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Technology diffusion in industry: an empirical investigation of technological adoption in Greek SMEs.

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Abstract

The thesis is about the spread of technology in the economy. More specifically it concerns the adoption decisions of individual firms. The basic relationships between technology and the economy are outlined along with the main theories employed to explain them. A diffusion-centred typology of technology is constructed building on existing work. Following that, a review of literature on diffusion and its associated measuring and modelling techniques is undertaken. Valid determinants of diffusion are identified in empirical literature. The above theoretical framework is used to analyse the technological performance of the Greek economy. Traditional technology policy is looked at and a 'technological map' of Greece is constructed. The map presents an overview of the current situation with regards to the diffusion and creation of innovations. The main country-specific factors affecting the process of diffusion are also identified. Informed by both theory and Greek reality a methodology is presented for an original survey in small and medium enterprises (SMEs). The empirical part focuses on the stage of diffusion concerning individual adoption decisions. An accompanying econometric model (logit) is used to explain the adoption of Internet Enabled Personal Computers (IEPCs) by SMEs. Results suggest that learning effects, the perceived availability of financial capital, perceived threat from competition, perceptions regarding the technology's life expectancy and linkages with multinational enterprises (MNEs) are strongly associated with instances of adoption. The author contributes an original insight into the adoption determinants pertinent to the Greek context. Finally, the findings of the survey and its empirical analysis are combined with secondary sources to construct tentative policy suggestions.

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This work is dedicated to the person without whom nothing is possible.

to my wife,

Rosario Bataná Martin

Author's Declaration

I hereby declare that this work has not been submitted for any other award. In addition, I affirm that the present thesis is the product of my work alone.

Dimitrios Pontikakis

Chapter 1 - Introduction and Methodology

1.1 Introduction

The importance of technological diffusion, that is the process by which the use of new technology spreads among a pre-specified set of adopters, has been expressed in policy directed documents by the OECD (1992) and (1996), the European Commission (1995) and recently the Greek Government's "*Greece in the Information Society: Strategy and Actions*" (1999). Policy makers now agree that the efforts of searching for new technologies should be equally balanced with efforts in implementing existing technology successfully.

In the contemporary world, understanding the economics of technical change is more relevant than ever. Advents in the fields of information and communication technology and biotechnology present huge opportunities. In information technology in particular, technologies are being replaced so rapidly that the speed of technology adoption could determine a firm's survival or lead to competitive advantage. From a macroeconomic viewpoint the successful assimilation of technology can even foster economic growth and act as a guarantee of sustainable development.

In popular perception, technology is a term that denotes little more than technical concepts as they materialise in the sciences and engineering[1]. The production of technology is a privilege enjoyed only by humans and it is the most striking

[1] The term itself is derived from the Greek '*technologia*', meaning systematic treatment of an art or skill (Oxford Dictionary, 2000). Therefore it is by definition referring to the practical application of knowledge in order to accomplish a task.

manifestation of that quality that sets us humans apart from other primates[2]; intelligence. It plays a central role as an enabling agent in human practices such as socio-political organisation and economic relationships. As a consequence, in the field of economics the meaning of the term 'technology' is much broader, *encompassing not just technical change* (as for example in engineering), *but also expertise, revolutionary methods* (as for example in management) *and innovative ideas in general.*

The importance of technology in our everyday life has always been acknowledged however until relatively recently its effect on the economy was thought to be indirect. It was only in the second half of the twentieth century that systematic economic research attributed to technology marginal increases in productivity and eventual economic growth (Solow, 1956). There is now consensus among economists that technology has been largely responsible for achieving and sustaining current levels of human welfare and that it is an essential factor for further economic development.

Despite the fact that innovation, i.e. *the production of new technology*, is incredibly important in economic terms, a number of economists (Mansfield, 1961; Solo, 1966; Rosenberg, 1976) felt that the real economic yields presented by an innovation at any given time hardly justified the attention it has received. Especially, when they found evidence that a number of potentially revolutionary technologies that are readily

[2] Differences in cognitive abilities are ones of degree, but their consequences are rather absolute. While occasional and isolated tool use is now thought to be common among (and not confined to) primates (McGrew, 2004), humans have a monopoly on the systematic creation and propagation of technology, with remarkable effects on our ability to harness nature. The creation, use and proliferation of technology throughout society lie at the very heart of what makes us human.

available are not utilised by economic agents (Griliches 1957; Mansfield, 1968; Rosenberg, 1986; Stoneman, 1995). So, they believe that the efforts of finding new technologies should be equally balanced with efforts in implementing existing technology successfully. Indeed, studies in the field of technological diffusion are an even more recent development in economic literature. Economists have analysed extensively the contextual conditions that are more conducive to innovation but traditionally the conditions under which these innovations are adopted by individuals has been the realm of other social sciences such as sociology and psychology.

As a direct consequence of the lack of economic research as far as diffusion was concerned, prior to the 1960s policy makers had largely overlooked the aspect of diffusion while formulating policies on technology. Governments invested heavily on the production of new technology but wrongly assumed that as soon as a technology is available it would somehow automatically diffuse and its spread would benefit the whole of the economy evenly. At the same time, private agents would invest on technology research for precisely the opposite reasons; to obtain a competitive advantage or even a temporary monopoly and retain it by using legal instruments (patents) to prevent its diffusion (albeit with varied success). On one hand one could be faced with a situation where a technology with proven labour-saving and other positive qualities has been largely under-utilised in an economy[3]. On the other hand, technologies that may be prevented from diffusing by patents and copyrights

[3] Examples of more efficient technologies that failed to diffuse include; the Dvorak Keyboard, the British-designed Acorn Computers and the IBM OS/2 operating system that was arguably more advanced than its commercially dominant competitor at the time (Windows 95).

eventually do diffuse much earlier often to the innovator's dismay. What really determines whether a technology diffuses then?

The theories that have emerged in recent decades are far from uniform. In the due course of the present thesis the author attempts to present, categorise and assemble in a unified and comprehensive manner relevant literature the contribution of which on the subject has been substantial.

Existing economic theory and measurement techniques are still a long way from assessing the exact role of technical change - as distinct from all other factors - in generating the rise in production that is essential for growth. As Rosenberg (1976) suggests the contribution of technical change itself will have to be established through the study of diffusion. That is because new technologies (whether they are products, processes or mere ideas) are of little importance in economic terms until they are actually *utilised* by economic agents. The study of diffusion enables us to develop a closer understanding of the rate at which new innovations, once invented, have been translated into events of economic significance.

Diffusion, as a generic concept has been defined as "*the process by which an innovation is communicated through certain channels over time among the members of a social system*" (Rogers, 1983: 5). The definition supplied by Rogers (1983), is applicable throughout the spectrum of the social sciences. The above definition is complemented by the one supplied by Karshenas and Stoneman (1995), whereby diffusion is '*the spread and/or ownership of new technology*'. In addition economists distinguish between two different types, or rather stages of diffusion; diffusion of information and diffusion of adoption. Diffusion of information occurs when economic agents (be they firms, other organisations or individuals) become aware of the existence and availability of a technology. Once they are aware of the technology's attributes economic agents make a conscious decision on whether or not to adopt it (diffusion of adoption), their decision based on a variety of factors. The focus of this study will be the identification of these factors, building upon existing literature and placing emphasis not only on the decision to adopt, but also on the speed of adoption and the technology's subsequent success in meeting adopter's expectations (in terms of profit, cost-reductions, productivity, etc).

Diffusion does not occur instantly, and the speed of adoption has been found to be related to both communication issues (the diffusion of information) and factors related to the economic agents' characteristics, strategic behaviour (acting upon expectations), the attributes of technology (relative advantage, compatibility, complementarity, complexity, trialability, cost, life expectancy and success of implementation) and environmental factors (economic climate, social attitude or culture towards technological change, openness of the economy, legal considerations). As an indication, Stoneman (1995) argues, it would not be unusual for the time period between the first use of a technology and say 90 per cent usage of that technology to take several decades rather than several years. The present study is concerned with inter-firm diffusion that is the diffusion of productivity-enhancing processes or products. Additionally, inter-firm diffusion does not refer to the level of use of technology by firms[4] but rather to the number of firms using new technologies in a specific industry or sector. Thus, in essence, inter-firm diffusion is concerned with technology adoption decisions.

1.2 Statement of the Research Problem

There is little doubt that firms can reap enormous benefits by introducing new technologies. The focus of a firm's technology policy is very much determined by the nature of the benefits they seek from technology. Technology may translate into marketable products and services or may become incorporated in the organisation's operational structures. Therefore the author chooses to make an obvious distinction between technology that results into or is expected to result into either:

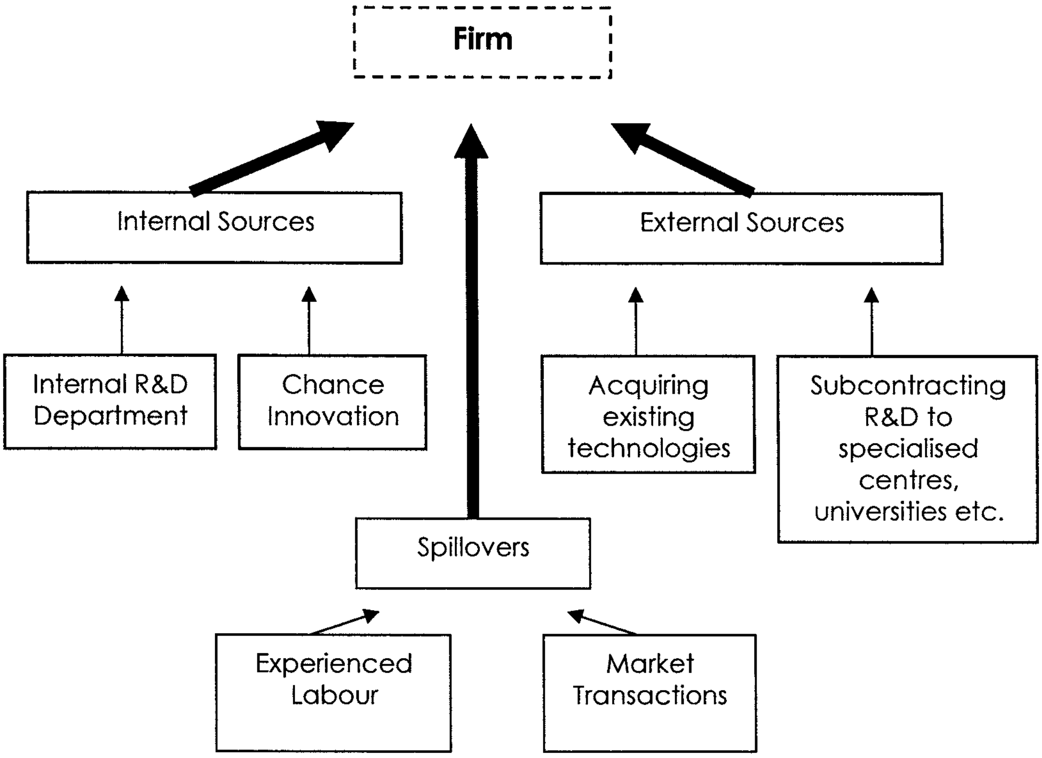
(a) *market benefits* – new/improved products and/or services that enhance the company's position in the market;

(b) *firm benefits* – technologies with labour/cost saving qualities that result in economies of scale in production/operation.

The distinction is merely a conceptual one as in practice most firms are motivated to pursue new technologies by a combination of market and firm benefits. Albeit, the distinction is useful in helping one understand why firms turn to such diverse sources for their technological needs. As illustrated in Figure 1.1 technology can be obtained by either internal or external sources.

[4] Known as 'intra-firm' diffusion.

Figure 1.1 - General Sources of Technology for Firms



The firm can generate new ideas, processes and general innovations internally. This would often entail an internal research and development (R&D) department that specialises in seeking new technologies that best match the company's needs. Possessing an internal R&D department is an ideal situation a company would want to be in, even if the amount of original research emanating from it is limited. On one hand it ensures that the firm's managers are kept updated with technological developments (what Julien (1998) refers to as 'technological scanning') and can thus make decisions with regards to the adoption of a technology as soon as it is available. On the other hand, the existence of an R&D department could help the reverse engineering of existing technologies and also enhance the prospects of a successful implementation of an externally acquired technology. However, the cost of an R&D department is prohibitive for the majority of businesses and particularly for SMEs.

There has been a lot of work suggesting that innovation is critical to the long-term success of every company[5]. Policy making has been often directed at stimulating the generation of new ideas at the firm level regardless of firm size. However research shows that such a generalised view is unrealistic[6]. Only companies that have achieved a critical mass are in a position to maintain a fully fledged R&D department and where innovation does occur in smaller organisations it is non-systematic, producing occasional chance innovations and therefore unsustainable. Large enterprises, such as multinationals can also take advantage of their diverse network of activities across many different operational environments and achieve economies of scale in the production of technology (Shy, 2001). On the contrary, smaller firms may have to opt to subcontract the creation of innovations that would help them launch new products and services or improve existing ones. Common subcontractors of such activities are universities, and specialised research centres. Even this option though is conditional to the company having a long-term strategy and adequate funds to finance such endeavours, both of which are generally common only in larger enterprises or those that are somehow affiliated with multinational enterprises[7].

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[5] Dosi (1988) presents a comprehensive review of literature on the effects of innovation on the workings of the firm. More recently, Baumol's (2002) work elevates innovation into the single greatest source of firm dynamism.
[6] Rosenberg (1976) and Julien (1998) refer to research indicating that the internal generation of innovations is closely linked to the size of the firm. Empirical research by Souitaris (2002) in Greek companies corroborates this assumption.
[7] Research by Blomström and Sjőholm (1998) verifies this argument.

Technology can also be obtained through what are known as 'technological spillovers'. The term refers to the inadvertent transfer of technology across distinct operating environments (be they countries, industries or firms) as a side-effect of another activity. Typically, spillovers occur as a by-product of the employment of workers who bring with them not only their occupational experience but also their technological experience[8]. Again, such occurrences are common when staff may have worked in the past for a highly innovative employer. The experience they have gained there may constitute an immeasurable asset for prospective employers. Such advantageous knowledge could include working experience of performance and quality enhancing methods; staff may have become accustomed to and become capable of technological scanning; importantly their previous adoption and innovation experiences may have positively predisposed them towards the further adoption of novel technology and its effective assimilation. Less common are spillovers occurring as a by-product of purchased products and processes as they can only materialise in the context of a chance discovery, where an existing idea finds a new use in the form of a marketable product or service.

There are instances where human expertise can prove pivotal to the development or adoption of a specific technology. Occasional spillovers usually make a one-off contribution to the firm's technological capital. A long-term human resource strategy that actively encourages spillovers and is prejudiced in favour of innovative employees could, in theory, do more than a simple incremental increase in technological stock. It could improve the firm's abilities in technological scanning, in

[8] Occurrences of technological spillovers are well documented; see Coe and Helpman (1995), Chen (1996), Jones (1996) and Blomström and Sjőholm (1998).

determining optimal adoption time and create an environment that eases intra-firm diffusion. Nevertheless, the occurrence of spillover effects is difficult to calculate and hard to rely on; with few exceptions[9] it is impossible to guarantee that hiring experienced labour will result in the effective utilisation of technology. Difficulties also arise in identifying and employing workers with the needed expertise; there exist practical difficulties in communicating and certifying technological competencies. Traditionally, educational qualifications have acted as a convenient measure of employee suitability but have proved somewhat lacking for the purpose of encouraging technological spillovers. In the light of the contemporary breadth and magnitude of scientific and other expert specialisations more sophisticated human resource mechanisms are called for. There have been recent attempts to cater for such needs through national[10] and international detailed skill databases for scientists and engineers though such attempts are very much at an early stage. Spillovers can be encouraged; however, their non-systematic occurrence means that firms should use them as part of a wider strategy in their technology decisions.

Finally, Figure 1.1 illustrates that technology can also be acquired; this source of technology is less advantageous for those firms that want to market the technology itself (market benefits). Indeed, copyright legislation may prohibit them from doing so by creating a temporary monopoly for innovators rather than adopters. The

[9] Such cases may arise when a technology is introduced to meet a specific need; a need which can be described and communicated effectively and can therefore be matched with a person specification. This is only possible within the boundaries of a long-term research project and large-scale adoption ventures which few firms can afford, typically larger ones.

[10] In Britain the National Office of Statistics has, as a first step, began collecting data on the number of doctoral scientists and their specialisations. In the United States, the National Science Foundation has for a number of years been collecting detailed data on the 'Science and Engineering' workforce. Notable is also the attempt of 'Expertise Ireland' to provide a comprehensive database of researchers and their skills in the Republic of Ireland.

acquisition of either a product or process technology can be beneficial for the firm's operations by raising its productivity levels and creating new opportunities[11].

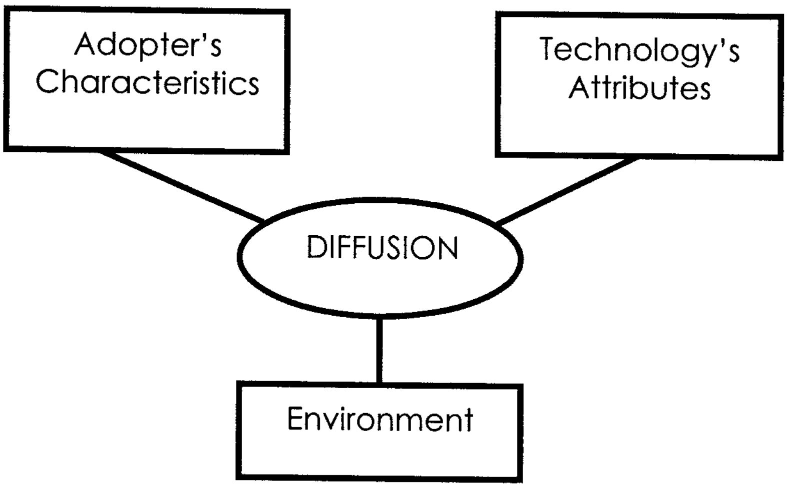
In light of the above, it is only natural that most companies will turn to the market of existing innovations in order to enrich their technological capital. Their quest to update their technological capital is seldomly without obstructions; the problem lies with the fact that *the diffusion of a technology is neither instantaneous nor homogenous*. Firms are not enjoying the positive effects of technology adoption because they are often prevented from adopting or adopt at a later stage when the innovation yields diminishing returns. Even when adoption occurs, underutilisation of the technology could lead to a less than optimal result. One could argue that strategic considerations on the part of the firm (e.g. with regards to the technology's appropriability) are often to blame for the time lag between technological innovation and technological adoption[12]. Yet theoretical work has shown (Reinganum, 1981 and 1983) that these considerations are only relevant when perfect information is available – an assumption that is not always realistic.

The lack of information has traditionally been thought as the main inhibiting factor in the diffusion of technology (Griliches, 1957; Mansfield, 1962). Later works (Mansfield, 1964; Davies, 1979) made a logical distinction between information spreading and the decision to adopt a technology. Even after information about the availability of a suitable technology spreads, firms may choose to postpone adoption.

[11] ICT technologies in particular can extend the reach of the company's operations, create new markets for the company's products and services and provide extensive information upon which to make management decisions.
[12] This is an area of technology diffusion that has been documented through the application of game theory. See chapter 3 for more details.

Therefore, under the assumption of perfect information, the decision to adopt is a composite of multiple determinants. Figure 1.2 illustrates the complex three-dimensional sets of factors influencing the adoption of a technology by firms and its consequent diffusion across an industry or an economy.

Figure 1.2 - Determinants of Technology Diffusion



These sets of factors include (but are not confined to) the adopter firm's characteristics (e.g. size, human capital, structure, behaviour), the technology's attributes or qualities (how good a fit it is for the firm in question) and environmental factors such as the macroeconomic environment, the existence of physical infrastructure, supporting organisations and institutions and even socio-political culture.

Such is the complexity of the process involved that an overarching, all inclusive theory that holds true for all types of technology, industries and environmental factors borders the impossible. A testable hypothesis though within a well defined environment (that of the Greek economy) with a limited time frame and a technology of broad appeal could provide valuable insights into the workings of the process within that particular environment and allow one to draw comparisons between different environments.

Thus the author has chosen to research available diffusion literature for an insight into the decision to adopt. In particular, adoption determinants relating to economies in transition (such as Greece), smaller firms (the dominant form of business organisation in Greece) and network technologies (such as computers) are sought after. The author aims to model and analyse the decision to adopt technology empirically, with a view at providing useful suggestions for both policy makers and managers alike.

1.3 Aims & Objectives

The present thesis aims;

(i) To provide a representative review of the vast amount of literature on the subject (Chapters 2&3).

(ii) To review and theoretically assess the Greek technological landscape; to investigate existing institutions promoting innovation, government policies and firm strategies related to technological diffusion with reference to their effectiveness under the light of the major economic theories on diffusion (Chapter 4).

(iii) To design and perform an empirical data collection related to Greek SMEs, examining the diffusion path of a specific technology over time (Chapter 5).

(iv) Existing literature has already identified many important factors influencing the spread of an innovation. The contribution of the present project will be to determine the ***relative weight*** of different factors affecting the decision to adopt in the context of the study (i.e. Greek SMEs) through comparative data observation, modelling and analysis, and determine the importance of two new factors (the success of previous experiences with similar technologies and the importance of the perceived life expectancy) (Chapter 6).

(v) To compare the resulting findings from the Greek context with findings from similar studies in other economies, thus spotting out characteristics and trends which are distinctive of the Greek economic environment, corporate culture and public governance (on-going aim).

(vi) To critically analyse and evaluate any conclusions drawn and creatively synthesize a comprehensive 'blueprint' (policy recommendations for government and firms) for the active encouragement of diffusion (Chapter 7).

1.4 Methodology Rationale

The present section attempts to outline in an analytical manner the methods and rationale behind their usage, employed in this project as well as present considerations and limitations. It considers the selection of appropriate research techniques and tools in order to explore the research topic, and the impact of the context of the study upon the methods and approaches selected. A sufficient description of the methodology used is of extreme importance because the reader can follow the logical path of the author's thought process. Employing and adhering by a strict set of methodological rules ensures that the author follows a clearly defined path, thus avoiding both omissions and repetition, ensuring the relevance of included material and effectively achieving the original objectives.

1.4.1 Qualitative Research

Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. Examples of qualitative methods are action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Bryman, 2001). Qualitative research methods are designed to help researchers understand people and the social and cultural contexts within which they live.

The two general ways of approaching qualitative research are the 'deductive' approach (moving from general to specific) and the 'inductive' approach (moving from specific to general). The deductive approach is more associated with objectivism and positivism while the inductive approach is more associated with phenomenology, subjectivism and anti-positivism.

1.4.2 The deductive approach

This includes the development and verification of a theory and is often thought of as scientific research. Bryman (2001), describes the characteristic stages of the logical process of deduction and presents them in the following chronological order;

(a) Theory
(b) Hypothesis
(c) Data Collection
(d) Findings
(e) Hypotheses confirmed or rejected
(f) Revision of theory

Robson (1993) compiled a comprehensive list of its characteristics. The deductive approach is usually employed in the search to explain causal relationships and involves the development of a hypothesis. In some cases quantitative data are used to test the hypothesis. The methodology followed under such an approach is described as a highly structured methodology, which facilitates replication and ensures reliability. It is also characterised by ‘reductionism’ – i.e. the questions sought are reduced to the simplest possible elements for testing. At the same time the deductive approach tends to generalise its findings, using samples big enough to suggest a general trend.

The present work is above all based on the deductive logic of testable hypotheses. Previous work and, in particular, established empirical and theoretical contributions are used to reach context-relevant hypotheses. Their testing and any conclusions drawn adhere by this approach. Moreover, an on-going concern has been the process of reductionism; simplifying questions and attempting to single out the most important influences. In spite of using a relatively small sample in the empirical part, the author's thorough work on ensuring the sample's representativeness, warrant the validity of findings in the general population.

1.4.3 The inductive approach

Research using an inductive approach is particularly concerned within *the context within which the events are taking place*. It usually begins with a narrow set of research questions which are specific and act as guidance. As evidence is amassed, the cases that do not agree with the existing model are evaluated and the model expanded to accommodate them. This process of accommodation (by model reformulation) continues until a satisfactory, over-arching explanation is obtained (Wiersma, 1995). In other words theory follows the data rather than the other way round. This approach has been developed within the social sciences because it is believed that it is not possible to identify causal links without understanding the ways in which human-beings interpret their social surroundings. In contrast with the deductive approach which is confined to the testing of a single theory, the inductive approach has the advantage of proposing alternative theories.

Given the topic in question and the solid theoretical underpinning provided by the works of Griliches (1957), Stoneman (1976), Rosenberg (1976 and 1986), Rogers (1983), Lundvall (1992) and Karshenas and Stoneman (1995) the need for theory reformulation appears minimal. As the empirical results suggest, the existing theoretical frameworks explain adequately the Greek diffusion experience. It is unavoidable though to question the applicability of traditional policy responses to technological inadequacies. Therefore, on a few occasions the author makes use of elements of inductive reasoning - but ones that fall short of proposing alternative theoretical explanations.

1.4.4 Investigation of Secondary Data

According to Bell (1993), "*an investigation whatever the scale, will involve reading what other people have written about your area*". Therefore in order to obtain information and knowledge about the chosen subject area, it was also necessary to use secondary research. A number of textbooks on the subjects of the economics of innovation and industrial analysis were used as a starting point. Additionally, academic journals proved to be a valuable source of up-to-date information and they often helped to determine the choice of questions for the primary research. The author also utilises secondary evidence from working papers, the press and publications on the internet to gain a holistic view of the subject. One of the advantages of relying heavily on secondary data is that it enables to author to build upon the experience of numerous other studies, thus maximising the possibility of an original finding or contribution. Saunders (1997) counts the following advantages of using secondary data:

(i) Secondary sources help to avoid repeating work, which may be previously documented. Originality of research aims and findings can only be ensured by establishing, to the extent that is possible, what has previously been said.

(ii) On a number of occasions it is not economically feasible to collect data from primary sources and secondary sources may be preferred even if they compromise the research findings.

(iii) It can also be useful to compare data the researcher has collected with secondary data.

(iv) Re-analysing secondary data can also lead to unforeseen or unexpected new discoveries.

However, at the same time the challenge of integrity and cohesiveness arises, as the author has to critically select sources that are reliable and include the findings of studies the assumptions of which are fundamentally compatible to those of the present study. One should acknowledge that drawing heavily upon secondary sources, may cause serious misgivings;

(i) Some sources may be unreliable; special care should be taken to selectively utilise reputable sources, where possible subject to peer review.

(ii) Some information is out-dated.

(iii) The originality of the research is compromised simply due to the fact that many of the assumptions, predispositions and conclusions of other researchers may be irrelevant to the context of one's study and may lead to predetermined conclusions.

It is important therefore that a careful balance between utilising useful information and maintaining the notional and structural integrity of the project is achieved. The challenge is to adopt meaningful knowledge that will add to the content and assist the validity of the study while avoiding being influenced or biased by the style of other studies. Every effort has been taken in the present thesis to adhere by these principles as the author had to make such considerations an integral part of his research philosophy. At times, the interpretation of other empirical studies proved particularly challenging; the theoretical framework adopted by these studies often had a distorting influence and led to 'stretched' conclusions. The author had to carefully examine any conclusions drawn and extract factual information while avoiding any 'theoretical lens' diffraction.

1.4.5 Primary Data

The obvious advantage of using primary data is that they constitute an up-to-date account of the situation in the area of interest. Primary data can also be selected to best suit the needs of the researcher and their collection adds to our knowledge by often revealing concepts and relationships which have not been observed before. Thus, it ensures the originality of a research project's findings

Primary data is to be collected by way of questionnaire in order to complete a case study. Its purpose is to validate previous assumptions and at the same time, seek new data on popular perceptions, personal experiences and conceptual relationships. A case study is often thought of as the development of detailed knowledge about a specific case or a small number of related cases (Robson, 1993). A case study is also known as an attempt to understand the 'whole' by looking into one of its 'parts'. It allows the researcher to gain a competent understanding of the context of the research and the process taking place.

Perhaps, one of the major shortcomings of primary data resulting from questionnaires is that structured questions may imply or 'direct' the respondents to select certain answers and therefore produce the results that the researcher is expecting. That is why special care has been taken to avoid suggesting particular answers. Particularly when quantitative data is sought, primary research is limited in flexibility and the amount of input the respondents are allowed to make.

Such limitations in flexibility are avoided in the present study by using an econometric model which is essentially qualitative, since its tests for categorical outcomes. Every effort was also taken to neuter the author's expectations when editing the questionnaire.

1.4.6 Ethical Considerations

Situational, physical and other advantages give rise to inequalities in the distribution of resources and personal liberty. Ethics have a social utility; humans devised ethics as a response to some of these socially undesirable inequalities. So, even when the situation permits it, ethical beings will not engage in activities giving rise to such 'unjust' outcomes. For instance, ownership rights could not have existed without the moral legitimacy contributed by the evolution of the concept of justice. Breaching ethical 'rules' may yield individual benefit, but does so at the expense of others and therefore ultimately harms common good. As such, ethics is a focal point of human progress and a tell-sign of deterministic intellectual emancipation. With research being the *modus operandi* of the progress of human knowledge it is extremely important that the present work complies with all ethical conventions.

With regards to ethics, special care was taken when dealing with information that may be deemed private. Maintaining the research project's integrity demanded compliance with ethical considerations as declared by both law and convention. The questionnaire in particular has been designed to collect data that may be deemed sensitive. To alleviate possible apprehension on the part of the respondents, a clear statement of purpose was included in the first page of the questionnaire. This was followed by a declaration of strict confidentiality, assuring respondents that data from this survey will not be shared with others. In addition the declaration states that in the event of publication of the study's findings extra care will be taken to ensure that no clues are given as to the individual respondent's identity.

1.4.7 Choice of Methods

To begin with, a secondary analysis of literature on the impact of technical change on the economy in general is undertaken. This way, the significance of the topic area is emphasised and a greater understanding of the fundamental effects of technology is realised. In turn, the study focuses on examining the spread of technologies throughout the economy. The core of the project investigates how technologies diffuse among firms and industries and most importantly why. The deductive approach is used, beginning with a review of the theory, the formulation of a series of hypotheses and their testing. Following an in-depth exploration into the literature of technological diffusion the author assesses the validity of a number of econometric studies seeking to establish the determinants of diffusion. The studies concerned have utilised econometrics to model the diffusion path and measure the decision to adopt. Many of them are concerned with inter-firm diffusion and attempt to assess the degree of influence that different factors have on the decision to adopt. The author uses these sources in order to create an outline of the current theoretical framework on the diffusion of innovations and in turn draw heavily upon it.

Then an econometric model is selected which aims to test the importance of the various determinants of diffusion as identified by previous studies. The model is a qualitative one, seeking subtle relationships rather than absolute measurements. The primary analysis focuses on the Greek economy and more specifically on the diffusion of internet enabled personal computers (IEPCs) in Greek SMEs. Finding data on Greek SMEs did not prove easy – particularly as much of the existing work is in the form of working papers from Greek universities and government policy documents which are difficult to obtain. The compilation of information on the technological competencies of the Greek economy is something that has only been attempted once before (Korres, 1995). An overview of the technological landscape of Greece is undertaken and country specific factors such as the importance of the availability of financial capital and linkages with MNEs are taken into account. The model then tests the validity of previously cited determinants of diffusion (such as the size of the firm, compatibility, cost of implementation and relative advantage) along with two new ones; the success these firms have had in adopting a similar technology in the past and their perception of the technology's life expectancy.

The results from the empirical survey are analysed and compared against secondary sources. Tentative suggestions regarding policy are made in the final chapter. The methodological approach can be summed up in the following table (Table 1.1).

Table 1.1 - Methodological Approach

Research Approach	***Ontology***	***Data used***	***Empirical Part***	***Analysis***
Deductive approach; beginning with a review of the theory, the formulation of a hypothesis and its testing	**Constructionist hypothesis**; social properties are outcomes of the interaction between individuals rather than phenomena that exist anyway and separate from those involved in their construction	Lit. Review: **Secondary Sources** Empirical part: **Primary sources**	Data collection by **questionnaire**	**'Logit'** econometric estimation model, qualitative interpretation of findings, Comparative analysis with secondary sources

The original contribution of this project is thus multiple;

(a) The recognition of two new factors of diffusion (successful previous experiences and perceived life expectancy).

(b) A representative survey of literature on diffusion.

(c) An up-to-date survey of Greek technology policy initiatives and technological innovation and adoption indicators.

(d) The compilation of data on the adoption of ICT in a representative sample of Greek SMEs.

(e) A unique perspective on the methodological ranking of factors of diffusion.

(f) Determining the relative influences of established diffusion factors in SMEs within the context of an economy in transition.

Furthermore, in terms of ontology, the author chooses to adhere by the constructionist hypothesis. An implication of this hypothesis is that social properties are outcomes of the interaction between individuals rather than phenomena that exist anyway and separate from those involved in its construction (Robson, 1993). Hence, economic sizes are seen under the prism of interlinked structures; diffusion depends on inputs and linkages alike. The choice of a constructionist philosophy allows one to underline the importance of systemic links (innovation actors) and market transactions (user-producer relationships).

1.5 Thesis Structure

Chapter 1 is a 'theme-setting' chapter; it introduces the topic under investigation and it sets the broad research questions. The author emphasises the importance of technology for economic development and the relevance of diffusion in the economic process. A broad set of definitions are provided in Chapter 1. The overall aims of the project are outlined and are accompanied with a short review of alternative methodological approaches and the rationale behind methodology used in the present work.

Chapter 2 is the first part of the literature review. Being broad in its scope, it attempts to put forward major explanations about the role of technology in the context of economics. In particular it presents a brief typology of technology and defines numerous terminologies relevant to the study. It is in this typology that the author contributes a categorisation pertinent to diffusion. In the second chapter the author also presents a short outline of instruments aimed at the encouragement of innovation and diffusion. The importance of industrial structure is highlighted and economy wide facilitators of diffusion are contrasted against inhibitors. In addition, the international transfer of technology is looked at. Not least, the significance of 'national culture' is discussed.

Chapter 3 is the second part of the literature review; this time being specific to the measurement of diffusion. A historical review of the evolution of major theoretical approaches to diffusion is undertaken. In Chapter 3 the author undertakes a detailed analysis of the phenomenon of diffusion. Empirically established diffusion determinants are looked at in detail. Such determinants include environmental (macroeconomics and microeconomic), technological and firm specific factors. The theories of epidemics as well as rank, game and evolutionary theories are explored. Their contribution to our modern understanding of the determinants of diffusion is assessed.

Chapter 4 brings the focus of attention to the economy of Greece and its technological competencies. An overview of the current economic situation is provided with reference to innovation and diffusion related indicators. The Greek technology policy framework is analysed from a historical perspective and its effectiveness is established in the light of relevant R&D and diffusion measures. Topical studies of the Greek economic environment are drawn upon and, together with technological indicators, assist in the creation of a 'technological map' of contemporary Greece.

Chapter 5 sets the theoretical and methodological background for the empirical part of the project. The empirical part is a case study on the adoption decisions of SMEs in Greece. The selection of technology, its context and the econometric model for the analysis of results are elaborated. A literature-backed selection of determinant variables is explained and the chosen model evaluated. The rationale behind the empirical study is also explained and a set of hypotheses is devised.

Chapter 6 presents the results of the questionnaire survey and analyses the resulting data with statistical and econometric means. The final fitted model is presented and is checked for validity. Its results are discussed under the light of earlier hypotheses. The implications of the study's findings for Greek policy are also briefly discussed.

Chapter 7 concludes the thesis by relating the empirical findings to the Greek economic reality. Policy deficiencies are underlined and feasible actions are proposed. At the same time the author identifies examples of good practice. With the study being firm-focused, strategic proposals for firm managers are also put forward. Finally, further research leads are provided and the overall research findings are summarised.

1.6 Conclusion

The importance of the diffusion of innovations in the economy should not be underestimated; it is the use of technology that results in marginal productivity increases necessary for economic growth. The decision to adopt an innovation is complicated by the multiplicity of sources but also by environmental, technological and organisational factors. The spread of innovations among potential adopters is not a sole concern for economics; various social sciences and humanities have contributed to the literature. Such interdisciplinary attention has had an effect on the breadth of theoretical approaches employed to interpret the workings of diffusion and model the decision to adopt.

A solid understanding of diffusion theory hinges on knowledge of the role of technology in an economic context. This is the topic of the following chapter.

Chapter 2 - Technology and Economics: The Fundamental Relationships

The value of an idea lies in the using of it
Thomas Edison

2.1 Technology and Economics; The Historical Setting

Technology has been closely related to economic change in general and economic development and growth studies in particular. The industrial revolution has been the single most important event in the history of economic development. It is no coincidence that the modern understanding of economics as a social science began forming at a time that the mechanisation of production fundamentally changed Western societies. As Karl Marx would argue in his Communist Manifesto, capitalism only became possible when the underlying technological advances were in place. The very fact that the industrial revolution was the result of the establishment of observational scientific rationalisation[13] and consequently the systematic development of new ideas we now refer to as ***technological innovation*** serves to underline the importance of technology in an economic context.

Innovative ideas influence every aspect of human activity. It has always been apparent that technology is significant in economic terms not only as a factor of production but also as a facilitating agent for the conduct of trade and even the establishment of social and political systems. A number of examples point to that direction; it was the harnessing of water and steam power and the ensuing mechanisation of production that enabled the industrialisation of Britain in the 18th century; the Moorish Empire would have never dominated trade in the Mediterranean during the 11th and 12th centuries without their navigational advances (such as the

[13] The industrial revolution coincided with a period in Europe characterised by a move away from supernatural and divine explanations of reality towards logic and deductive reasoning. This shift is attributed to numerous advances in science and philosophy, which signalled the birth of modern science, that is science based on undisputed facts and verified by testable propositions.

compass and the astrolabe); and the ancient Greeks only developed the ideas of democracy, freedom of speech and consequently entrepreneurial freedom to the extent that their limited advances in philosophy (another form of technology) permitted them to.

It should not be surprising then that innovation and new ideas are much sought after both by individual firms and national governments. Individual firms are drawn to innovation by a thirst for the exclusive benefits a temporary monopoly grants to innovators. Governments have used technology not only for its obvious quality – as a response to a given need – but also as a pawn in political and strategic antagonism[14].

From a purely functionalist perspective, innovation is so desirable because it can generate large cumulative gains in productivity. Since the early 20th century technology in economic literature had not yet been attributed its current status as the major factor affecting economic growth and eventually causing structural change. As a rule, technology was seen more often as a consequence of structural change, rather than the cause of it. This is evident in the writings of theorists as diverse as Adam Smith, David Ricardo and even Karl Marx. Adam Smith in his *Wealth of Nations* (1776) was perhaps the first theorist to recognise the impressive effect process

[14] The Cold War was characterised by antagonism not only in geopolitical terms but also in terms of science and technology. Not infrequently were technological advances used as propaganda instruments. The so-called 'space race' is a well known manifestation of this rivalry. Thus the drive for technological supremacy was partially motivated by the need to portray each of the rivalling politico-economic systems as the most efficient and add legitimacy to their respective efforts to prevail.

technologies have on productivity[15]. However he viewed further technological change as the result of economic growth. Even though Karl Marx had also recognised its importance as one of the means of production, he ignored the wider structural implications in the economy as a whole[16]. Rosenberg (1976) suggests that Marx was not a technological determinist, but rather viewed technology as a small piece of the puzzle which forms capitalism.

The first systematic attempt to incorporate the element of technical change and link it with economic change was made by Marshall (1920). In his work *Principles of Economics* he drew analogies between economic relationships and Darwinian biology, developing what he called 'economic biology' thus giving birth to a new strand of economic thought known today as evolutionary economics. Marshall's enlightened work argued human societies are very much like a living organism and that technical change is their evolutionary mechanism. Just as living organisms evolve through natural selection (i.e. the successful genes, are the genes that yield a positive outcome[17] towards the survival of the species) and adapt better to their

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[15] As a first-hand witness of the Industrial Revolution, Smith places at the centre of his analysis the fact that greater productivity is derived from manufacturing. In his visit to a pin factory he observed that using ten men it created 48,000 pins a day whereas a traditional solitary craftsman working could produce one pin a day. Smith attributed this leap of productivity, to organisation and technology: the division of labour in which one man draws out the wire, another straightens it, a third cuts it, a forth points it, a fifth grinds the head, and so on through about 18 different operations; and, to the ability to utilise time saving machinery by which one labourer can do the work of many.

[16] Marx's means of production, refer to land and natural resources, labour and technology that are necessary for the production of material goods. Marx saw rapid technological development as a capitalist mechanism for profit ultimately resulting in conflict (Rosenberg, 1976). That is because the means of production change more rapidly than the relations of production (for example, it takes some time after a technology is developed to regulate the use of an earlier technology).

[17] For a clear and detailed analysis of theories on natural selection and their implications for both applied and social sciences see Dawkins R. (1989), *The Selfish Gene*, Second Edition, Oxford University Press. For explicit economic applications see Witt (1991).

changing needs, only technologies that are economically viable and useful (i.e. have some kind of positive yield) diffuse and become widely adopted.

Schumpeter (1942) considered technology as the main driving force of capitalism. Schumpeter recognised that entrepreneurs driven by their desire to achieve a monopoly (even if only a temporary one) concentrate their efforts on generating innovation and making it available to society in the form of a good or service. The incentive for profit maximisation through the monopoly yielded by an innovation is according to Schumpeter the competitive edge of capitalism when compared to alternative systems of economic organisation. He argues that despite the fact that only a single firm may profit from the monopoly set in place by a patent system, the society as a whole is able to reap the benefits of the technology's qualities being available. Galbraith (1956) expanded Schumpeter's ideas and applied them to oligopolies and duopolies, arguing too that the overall social benefit justifies the structure of technology markets and the existence of patents.

No single work on technology has had as a strong impact on economic theory though as that of Robert Solow. Robert Solow (1957)[18] in his article *Technical Change and the Aggregate Production Function* calculated that technological progress was responsible for about 90 per cent of economic growth output in the United States during the period 1870-1950. As Shepherd (1990) so eloquently puts it, Solow's work led to the realisation that a few years' worth of higher rates of innovation "*...could quickly outstrip the best possible results from fine-tuning static efficiency*" (Shepherd,

[18] Ominously, 1957 was also the year that William Shockley invented the transistor, thus making the ICT revolution possible. Griliches original work on diffusion was also published in the same year.

1990: 141). Solow managed to demonstrate in a systematic and coherent way what economists from as early as the 18^{th} century had been suspecting; the immense effect of technological change on social and economic development.

On the field of microeconomics, work by Griliches (1957) and Mansfield (1961) placed high importance on the aspect of technological adoption from external sources as a solution to enhancing a company's technological competencies. Mansfield found that many firms have so far focused on the creation of new technology often ignoring the fact that existing technologies may pose an alternative if adopted. It is rare to find an academic work on technological diffusion that omits to mention either Griliches' or Mansfield's work. Their contribution to the field has been immense and is still shaping the study of diffusion; it can perhaps only be appreciated by having a look at subsequent works that have taken their ideas further.

2.2 Technology Policy: Rationale and Actors

Questions on whether the government can and should influence the generation of new ideas date back to the industrial revolution[19]. The importance of technology for productivity increases, economic growth and overall human well-being is by itself perhaps the strongest argument for government intervention. Neoclassical economists have traditionally been opposed to any form of government intervention and argue that the market process itself creates sufficient leverage to encourage sustainable innovation. They point to the fact that the government may be ill-informed about the

[19] Provisions for patents in legislation appear as early as the 17^{th} century in Britain and the 18^{th} century in the United States.

economy's technological needs and that the direct funding of innovation may incur appropriability-related social costs. They do accept however that there are instances when the market lacks the financial incentive to grant the optimal social result. The familiar concept of a market failure is also relevant in the context of the generation and diffusion of technology. Monopoly power and its abuse as well as the provision of property rights are prominent examples of market failure. The government does play a central role in industrial structure; by regulating monopoly power on one hand while granting temporary monopolies in the form of patents on the other.

Technology policy is about promoting technological innovation and as such it falls within the wider scope of industrial policy; it shares many of its assumptions, its institutional framework and accompanying instruments. Industrial policy often seeks to reshape the structure of the industry in order to cater for market failures, whether technological in nature or otherwise. Policy responses vary from those centred on financial and human resource inputs to systemic ones emphasising institutional linkages.

First of all, governments create a supporting legal framework to encourage new ideas in the form of intellectual property rights and patents (discussed in detail in § 2.3.2). Direct government funding for research and development materialises in the form of financial support for research generating institutions and more recently in financing technological imports and localised technological diffusion. Of course, government commitment to universal education is also central to the innovation process.

Peterson and Sharp (1998) argue that research establishments, local and multinational firms as well as government authorities are important institutional actors for the promotion of innovation. Linkages between institutional actors involve more than the mere transfer of technology. In its flow from laboratory research to being a marketable commodity, knowledge has to be changed, adapted and even enhanced to meet the particular needs of its application (Freeman and Soete, 1990; Freeman, 1995). Over time, this has the effect of gearing all these institutional actors not only towards being innovators but also towards acquiring improved technological scanning and assimilation abilities. These abilities take the form of tacit knowledge that becomes embedded in the firm and is further enhanced over time. This activity is often referred to as cumulative learning by doing (Lundvall, 1992; Colombo and Mosconi, 1995). However, the creation of such knowledge is conditional on the presence of co-ordinated supranational, national and regional innovation systems that capitalise on interactive networking among actors (Lundvall, 1992; Edquist, 1997).

Innovation systems are commonly found at the national level and are also becoming increasingly common at the supranational level. There exist legal regulatory arrangements aimed at fostering a national innovation system covering areas as diverse as research, training and industrial structure. Human resource development occurring concurrently in leading research universities as well as in industry can encourage spillovers. Indeed, Peterson and Sharp (1998) point to the British model, whereby postgraduates are encouraged to participate in leading-edge research as a vehicle for spillovers. At the same time, universities are expanding their concerns beyond the traditional roles of education and research to include entrepreneurial objectives (Etzkowitz, 2003).

The current pace of technological development in network industries further encourages institutional networking. The life cycle of most technologies in the sector is very small; increased competition has brought technology substitution at speeds that are unprecedented in other industries. Even large MNEs aim to diversify their technology development programs in order to spread costs and minimise the risk of large losses. Most firms opt for strategic alliances and strong cooperation with other institutional actors rather than rely on their own research initiatives.

2.3 Technology and Industrial Structure

Technology affects not only productivity but can fundamentally alter the structure of the economy. At present, the most important reshaping of the global economy has been taking place as a consequence of the development and evolution of information, communication and transport technologies. Markets have sprung up where they did not exist before. Technological advances have given rise to new industrial structures with very distinct characteristics.

Industrial structure can also affect the generation, transfer and diffusion of innovations. Different competition regimes in particular have shown varying innovative competencies. The present section looks into the workings of this bidirectional relationship.

2.3.1 The ICT Revolution and the Emergence of Network Industries

The emergence of new technologies has had a particularly profound effect on the production process. This effect has gone beyond simple efficiency improvements; it has altered the very workings of the economy. Prominent social scientists such as Bell (1973) and Castells (1996) argue that in the last three decades of the twentieth century we are witnessing the advance of human societies to the age of information, the process itself described by many as an 'informational revolution' or an 'Information Technology Revolution' (Castells, 1996).

The subject revolves around the idea of this revolution, this landmark event that started in the 1970s and is still taking place at present. This event was the introduction of microcomputers in the market and their usage in a wide variety of human activities. Computers have thereafter infiltrated every aspect of our lives. Apart from personal computers, most household and business appliances today rely on a digital processor of some sort. The 'Millennium Bug' and the publicity it attracted, though possibly misplaced, poses a good example of the degree that our societies are dependent on information technology. The even more recent convergence of Information Technology with Communications Technology is set to take the information economy further.

As a result, information technologies have affected the very structure of industrial organisation. Literature in the field of industrial economics (Economides, 1996; Shy,

2001) has recognised that certain industries which are innovation intensive possess common qualities and therefore ought to be studied jointly. Technological advances have expanded the scope of service industries and created new markets for goods and services, with distinct characteristics. Such markets are the markets for telecommunications (telephony and data transfer services), information technology (computer hardware, computer software), banking services, transport services (airline and train industry) and even legal, consultancy and accounting services (Shy, 2001). Apart from depending on the continuous evolution of or having massively benefited from the development of, certain technologies these markets also have the following common characteristics that set them apart;

(a) Complementarity, compatibility and the existence of standards.
(b) Consumption externalities.
(c) Switching costs and lock-in.
(d) Significant economies of scale in production (Shy, 2001).

Network industries are driving the ICT revolution and form the core of what is known as the 'information society'. Firms in network industries are themselves producers of innovations and rely heavily on information and on newer technologies to achieve competitive advantage. They often have dedicated R&D departments which have as their primary mission the acquaintance and applicability assessment of new technologies. One can therefore safely assume that the diffusion of information about the availability of a technology occurs, if not instantly, then very fast. A focus on firms and technologies in such industries can help to isolate factors affecting the spread of an innovation other than information spreading which has already been exhaustively studied. In addition, one would expect firms operating within network industries to be among the very early adopters.

Strategic considerations and inherent firm and/or industry characteristics are poised to become increasingly important, in a global, increasingly integrated economy where information imperfections are less likely to occur. In recent years, especially in the fields of business studies and management, the study of easy, rapid and effective dissemination of information has generated a huge amount of literature, summarised under the heading 'knowledge management' (Matarazzo and Connolly, 1999; Martinsons, 1993; Galunic and Rodan, 1998). It focuses on the utilisation of IT in order to nullify the adverse effects of information mismanagement thus ensuring the effective utilisation of existing knowledge. One of the most interesting methodologies to emanate out of this field of study is data mining. Data mining techniques involve so-called 'artificial intelligence' algorithms looking for particular traits in vast databases, in a similar manner to the one performed by web search engines. Recent developments in data mining have resulted in customised software enabling organisations to continuously keep up to date not only with strictly technological but also legal, financial and industrial developments that are specifically relevant to the individual firm. Moreover, such techniques have also found application in technological as well as human resource and expertise scanning[20] (Fayyad et al,

[20] Data mining and database association methods have recently been employed in the search for new medicinal applications for traditional herbal remedies. Researchers at the Mayo Clinic College of Medicine in Rochester in the United States scan old botanical medicine texts (ranging from ancient times to modern alternative medicine) using advanced cross-referencing techniques against modern

1996). It is perhaps an irony that it is technology itself, which fundamentally influences the mechanisms by which innovations spread.

2.3.2 Patents, Innovation and Industry Structure

As soon as the importance of continuous innovation for economic wellbeing was realised, it was felt that steps should be taken to promote the generation of new knowledge. Governments have traditionally tried to provide incentives for innovation through elaborate legislative instruments known as patents. The term patent refers to the exclusive legal right granted to firms or individuals upon application to use a technology and exploit it commercially for a specific period of time. Patents are a widely used measure of innovation, despite the fact that in reality very few of them translate to marketable product or process technologies with a significant relative advantage.

According to neoclassical economists enterprises engage in research and development driven by profit. The inability of the producers of technology to fully appropriate the benefit of their activity causes the discouragement of technological innovation. In a free market, there is no motivation in place that will compensate the producers of technology for their effort into researching innovations. Private production of technology can be encouraged by the existence of property rights in the forms of patents, thus resulting in a temporary monopoly. Hence, patents exist to protect the innovators from imitators and thereby provide a profit incentive that should

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databases. The search is hoped to identify promising candidate (plant) species for further examination and screening. This technique is now known as *digital bioprospecting* (The Economist, 2004).

encourage innovators to take the burden for the cost of research and development. Thus, the temporary monopoly created by a patent can be thought of as the innovator's reward.

Neoclassical economists also argue that the promise of such a reward is much more efficient at stimulating innovative activity than is direct government funding. The surprise publication of the sequence of the human genome by a private organisation in 2001 (namely Celera Genomics) before the publicly funded Human Genome Project had completed its research targets stands as an outstanding example of the impact of the profit motive on the efficiency of R&D (The Economist, 2001). Many advocates of patents argue that in the absence of such a reward the overall incentive to innovate would have been lower, a situation that may arguably be detrimental to the general level of innovative activity.

This is however based on the assumption that the creation of innovations is synonymous to social well being[21]. Nevertheless, society realises the benefits of any given technology by using it, not by finding out about its existence[22]. Technological diffusion should therefore carry at least as much weight in policy making as the generation of new ideas. The existence of patents in their contemporary form gives rise to a paradox; overall social benefit from an innovation will only arise when the

[21] This is an assumption prevalent in policy directed documents by the EEC (1995) and the OECD (1997).

[22] There exists a wealth of examples of technologies which failed to deliver the expected benefits; the Segway personal transportation system was supposed to revolutionise urban commuting – nevertheless nearly five years after its commercialisation it is nowhere near having diffused. The Dvorak keyboard (an alternative keyboard layout to the established QWERTY arrangement) is also an infamous case of high promises and non-diffusion.

technology in question is adopted and used by everyone. By nature, patents obstruct the diffusion of innovations adding to the cost for would-be adopters. Consequently, one may accept that while patents increase the amount of innovative ideas, they do so at the expense of the probability of adoption. Whether patents in their current form are the socially optimum solution is an open research question. Their finite duration certainly offers some guarantee that patented knowledge will eventually diffuse widely[23].

There are also arguments against the universal applicability of patents. Profit is surely not the *only* motive for innovation. Among other things, curiosity may often drive researchers to extent the body of human knowledge (Mokyr, 2002). The significance of the profit motive may also vary from one scientific field to another. Schmookler (1954) hypotheses that novel fields initially experience a very rapid pace of invention but that, given enough time, this rate progressively diminishes, until it reaches a level comparable with older fields. He attributes this not to profit-seeking or expected market benefits but what he calls 'technological trajectories', whereby for the same amount of investment, new fields exhibit greater inventive yields compared to older ones. More recently, Bessen and Maskin (2000) showed that patents in industries that are innovation intensive appear to have the reverse effect to the one intended. Instead they argue, patents in some of the most innovative industries such as software, computers, and semiconductors actually promote a permanent rather than a temporary monopoly. Many innovations in ICT may have a large-scale impact on the industry,

[23] Nordhaus' (1969) model attempts to address the trade-off between social and private gains from innovation by seeking an 'optimal' patent duration.

to the point of creating new markets[24] where they never existed before. In such a scenario the original innovator quickly captures an overwhelming majority market share – a first mover's advantage. This market share is retained by incremental improvements, which due to the first mover's advantage, the original innovator is in a better position to deliver. By this stage, users of the technology are less likely to switch to a competing innovator, prevented by fears of incompatibility and the habitual familiarisation they have acquired with the original innovator's technology.

Bessen and Maskin (2000) go on to argue that such monopolies actually discourage innovation; market entry becomes prohibitively expensive, while monopolists have little or no incentive to innovate. Shepherd (1990) also points to the fact that high levels of market concentration can prove detrimental to innovation due to what he calls a "replacement effect" and is more widely known as the "Arrow effect". Arrow's (1962) influential work on innovation races suggests that patent holders are less likely to strive to generate new ideas as the expected benefit from doing so is only the difference between expected profits obtained with the next technology and the current one. In markets for incremental improvement and mutually exclusive innovations (such as computers and communication technologies) the generation of new technology by a monopolist would have a negative effect on its technological assets. That is because the monopolist would not maximise the profit potential of

[24] QDOS (introduced in 1980, Quick and Dirty Operating System, later renamed MS-DOS) was a versatile PC operating system that gave Microsoft a foothold at the software market and paved the way for eventual dominance in the form of Windows. It was this first mover's leverage that enabled Microsoft to acquire its impressive monopoly and shape the software market to the point of creating industrial standards (e.g. ActiveX, FAT and NTFS file systems, DirectX, .Net Framework, Microsoft MPEG4, Microsoft Point to Point Encryption and others) and showing the way to further developments in the industry.

older technologies; in effect, in such a case, it is in the monopolist's interest to stall innovation or at least its manifestations in marketable products and services. Contrarily, new market entrants are motivated to innovate by the prospect of all the expected profits from the new patent – but find it hard to enter a market dominated by a monopolist. This may indeed be the case with the American software firm Microsoft; despite the company's resources devoted to R&D, it is curious that a disproportionate number of innovations now incorporated into its monopoly product Windows Operating System were initially introduced by third-party companies and public research institutions[25] many of which have subsequently gone out of business. Nevertheless, Etro's (2004) recent work implies that monopolies can be highly innovative, provided there are no barriers to entry.

Until relatively recently ICT technologies had had weak patent protection (either because in much of the world governments were too slow to introduce relevant legislation or because they have been unable, and in some cases unwilling[26], to enforce it). Companies in the ICT industry have experienced widespread imitation of their technologies. Arguably, imitation has helped diffusion at the expense of innovation. Given that the social benefits from the adoption of ICT are so profound, the fact that imitation did occur (whatever the cause) is perhaps suggestive of a

[25] Examples include multiple user access pioneered in Unix-based operating systems, compression technologies (LZW, Intel, AT&T), multitasking (Apple and Commodore-Amiga), internet browsing (Mosaic, Netscape) and instant messaging (ICQ) among others.

[26] A study conducted on behalf of the Business Software Alliance (IPRC, 2000) indicates that software piracy reached endemic proportions during the 1990s in much of East Asia, Eastern Europe, Africa and Latin America. It also claims that patent breach is still common practice in the IT sector. Software piracy may have been tolerated in developing countries mainly because of cost considerations. The study however suggests that piracy levels have declined dramatically in recent years. One explanation for the recent decline may be that governments in the developing world decided to take tougher stance with regards to piracy as a form of protection for their own fledging ICT industries.

market-correction mechanism. A corrective mechanism that jumps into action when the perceived relative advantage of diffusion by imitation and patent breach so massively outweighs the penalties for doing so.

Admittedly, in the long term the existence of some sort of legal provisions for intellectual property appear as an institutional prerequisite for the establishment of notable research output throughout the economy. Countries with weak patent legislation have been unable to produce notable levels of domestic technology generation and chronically rely on technology transfer from abroad (e.g. the so-called Asian 'Tigers[27]'). The on-going discussion about patent reform in much of the Western world may well benefit by considering instruments relating patent applicability and duration to an industry's technological trajectory.

2.4 Types of Technology

In economics technology in itself is seldomly relevant; it is the implications of the existence, acquisition, use and continuous evolution of the technology that are important. Changes in technology have proven themselves to have such an impact on the workings and development of an economic system, on productivity and market structure that prompted a direct and systematic study of the ways in which technical change occurs and the different types of technical change. The author so far distinguished technology in terms of the motivation for its development and use

[27] South-Korea, Singapore, Taiwan and Hong-Kong; collectively referred to as the 'Asian Tigers', a reference to both the countries' current prosperity and their rapid growth record.

(technology expected to yield either firm-benefits and/or market-benefits). The present section looks into various other types of technology, in terms of its nature, the process that generated it and, for the first time, its expected diffusion prospects.

2.4.1 Product and Process Technologies

Technologies are distinguished in two broad categories; *product* and *process* innovations (Shepherd, 1990). On one hand, process innovations simply alter the way products are made, by creating novel ways of carrying out operations and providing marginal increases in productivity. Examples of process innovations include a new management concept, a new scientific measurement technique, a different way of inputting computer data and a new educational method. On the other hand, product innovations create a new good for sale, without any change in the process (Shepherd, 1990). Product innovations create a new good which could enhance the firm's market share or possibly create a whole new market. Examples of product innovations include a better digital watch, a new type of video recorder, a more efficient algorithm for data compression or a new version of an established software product. It is important to note that the two kinds of changes may be distinct in principle, although it is more likely to encounter a mixture of both in practice. For instance there is the discrete possibility that the development of a process technology may ultimately give rise to one or more marketable products, which are product technologies themselves (Table 2.1). The distinction is still important though as it enables economists to assess the potential impact of an innovation.

Table 2.1 – Examples of Process and Respective Product Technologies

Process Technologies	*Product Technologies*
steam power	locomotive, steam boat
electricity	telegraph, street lighting, refrigeration
combustion, plastic polymers	automobile, airplane, cruise liner
transistors, semiconductors,	computers, consumer electronics
data compression, data encryption, radio communication	mobile phone, internet, wireless networks

The distinction between process and product technologies is often described as one between tangible and intangible technologies. Tangible technologies (though not necessarily products[28]) are technologies that exist in physical terms and are often referred to as '*hardware*'; while and intangible technologies are often referred to as '*software*'. The hardware/software terminology borrowed from the field of Information Technology is well suited in describing these two kinds of technology. For instance, computer hardware consisting of various electronic and mechanical components, optical media, numerous connections and wires is a typical example of what commentators have come to describe as technological hardware. In the same way, computer software with the instructions, commands and coded subroutines contains the 'mode of use' or an 'information base' for the tool (Rogers, 1983) and is in most cases almost synonymous to a process innovation. These two kinds are also likely to complement one another. At the same time though they are very likely to exhibit very different qualities which ultimately influence their adoption experience.

[28] A tangible technology may be by nature too diffuse to be marketed as an exclusive product – despite it existing as a physical entity; e.g. a new aircraft design, or a new mobile phone "form factor" (shape) such as a clamshell design – as its imitation by competitors is easy (simple observation is all that is required)

2.4.2 Autonomous and Induced Technologies

Furthermore technologies are distinguished according to the nature of the process that generated them. Official policy is often directed at encouraging the generation of innovations as a measure of social improvement. The obvious question policy makers are faced with in such a case is: "*Can we do something to stimulate invention? Or is it inevitable that some inventions will be made regardless of our involvement?*" It is often considered that if left to the market some technological advances that could potentially prove pivotal in improving general living standards would never materialise. This is because, the assumption goes, there are areas of scientific research that firms have little incentive to finance as there is no immediate application of the technology – hence no foreseeable possibility for a marketable product or service. Space exploration (which has resulted in some truly useful technological by-products[29]) is an example used frequently to illustrate such a case of market failure. It often takes the efforts of the public sector, either through its own R&D or concerted technology policy initiatives for such technologies to be developed. Hence, a technology may be *induced*. Policy makers usually employ a mixture of instruments aimed at 'inducing' innovations; intellectual property rights provide a profit incentive for innovators while government funding to private research organisations as well as governmental research institutions aims to generate knowledge with a view to benefit

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[29] The needs of space exploration drove the development of advanced materials (fire resistant fabrics, radiation insulation and plastics), avionics (engines, lighter materials and aerodynamic design advances), computers (networking, expert systems and data storage), new energy sources (solar panels) and technologies that found applications in modern medicine (ultrasound scanners, lasers). The current breadth of civilian applications for GPS technology (Global Positioning System) also poses a good example.

the whole of society. State-directed induction of technologies is not limited to their development but may also apply to the encouragement of their transfer and diffusion.

In many cases though, it is the market that comes up with innovations autonomously. Some innovations may be a natural consequence of previous discoveries and as incremental changes may be simply 'waiting to happen'. Such technologies can be described as 'autonomous', a term which may again refer to either their development, diffusion or both. Identifying a technology as one that is autonomous or induced can have important consequences for technology policy in the industry or field where it emerged.

The generic potential usefulness of continuous innovation makes a very strong case for government involvement. Critics however may counter that there is little social gain to be had from incurring social costs (e.g. in the form of spent government funds) in order to encourage innovations that may after all be autonomous. It is interesting that despite a considerable volume of work on the subject there is still little agreement over what policy regime is more appropriate. The intrinsic difficulty in identifying autonomous innovations as distinct from all others provides an added hurdle. A way around this problem is to aim to create an innovation-conducive environment and aim to improve the efficiency of any policy intervention. Certain traits among industries (competition, network effects) and firms (size, experience, behaviour) tend to give out clues as to the 'natural' innovators – those agents who need little or no help to come up with innovations that ultimately benefit everyone.

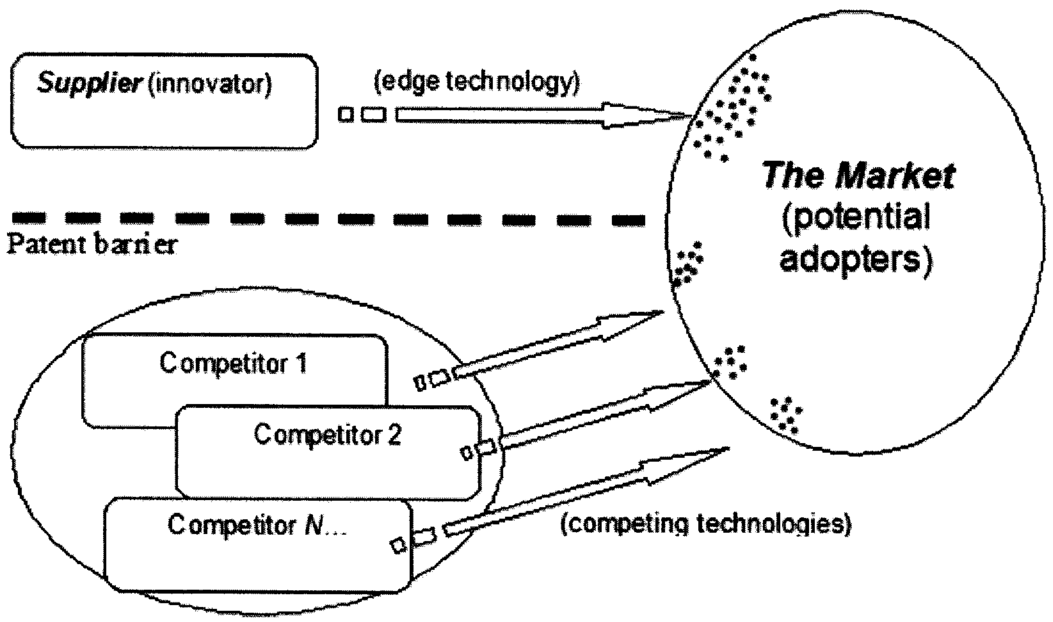
2.4.3 Edge Technologies and Industrial Standard Technologies

The technologies elaborated on so far, whether *market* or *firm* oriented, *process* or *product*, *autonomous* or *induced* have been technologies that firms essentially use to differentiate themselves and get ahead of competition. Whether aiming at improving efficiency within the firm or grabbing a larger share of the market firms look at technology for a competitive edge. I chose to term such technologies *edge technologies*, a term that makes reference to their purpose. Indeed the vast majority of all technologies ever conceived of are edge technologies. Competition for limited resources makes rational actors engage in a search for more effective techniques, preferential knowledge and efficient machinery. If the positive qualities of the technology are so precious one would expect firms to want to use it exclusively; indeed, innovators, firms which come up with new ideas, protect their ideas fiercely, whether termed intellectual property or industrial secret[30]. Intellectual property rights and patents prevent imitation by competitors and ensure the innovator is compensated or (depending on one's viewpoint) rewarded. Supply side diffusion (imitation by competitors) would work towards neutralising any market benefits. Maximising the diffusion potential of the technology may not be perceived as being in the innovator's best interest and is not an end in itself. The ultimate end is profit maximisation. Therefore, only demand-side diffusion, in other words diffusion among buyers of the technology is encouraged. With an edge technology, the innovator may carry on

[30] As an indication the European Patent Office has on file more than 45 million patent documents for at least as many technologies. In 2003 alone the total number of patent applications was in excess of 162,000 of which 60,000 were granted. According to the U.S. Patent and Trademark Office, in the United States the same figures for 2003 were 366,000 and 187,000 respectively.

being the single supplier of the technology to the market (Figure 2.1a) for years to come.

Figure 2.1a - The diffusion path of an edge technology



***NB*:** dots represent adopters of a technology.

As the innovator is concerned with its own profit maximisation the socially optimal diffusion level may not be reached for a number of years. It is nevertheless a short-term cost to society that is necessary if only to maximise the incentive for continuous and sustainable innovation.

In contrast, there are also technologies which are, from inception, intended to diffuse among actors in both the demand and the supply side. The author chooses to call them *industrial standards* as they are usually developed and promoted with the benefits of standardisation and interoperability in mind. These are technologies which depend on the existence of networks and usually provide a stepstone upon which new technologies can be created and new markets can be opened. As such they are important for the industry as a whole and their development sometimes reflects an understanding that cooperation in the particular technology can benefit the whole sector. As a consequence, the development of some of them may represent a collective effort by key actors in an industry; others though may be the result of a single company's R&D efforts. What makes industrial standard technologies so important as to deserve special mention is the fact that from their inception, diffusion is an end in itself even at the expense of short-term corporate profit.

On one hand, where the industrial standard technology is the result of the efforts of many, its diffusion is motivated by a desire to widen the market and increase the set of potential adopters. On the other hand, where the technology has been developed by a single innovator, the promotion of the technology as an industrial standard may in the longer term yield to the innovator the added benefits of technology lock-in (for adopters) and loyalty[31] payments (by imitators).

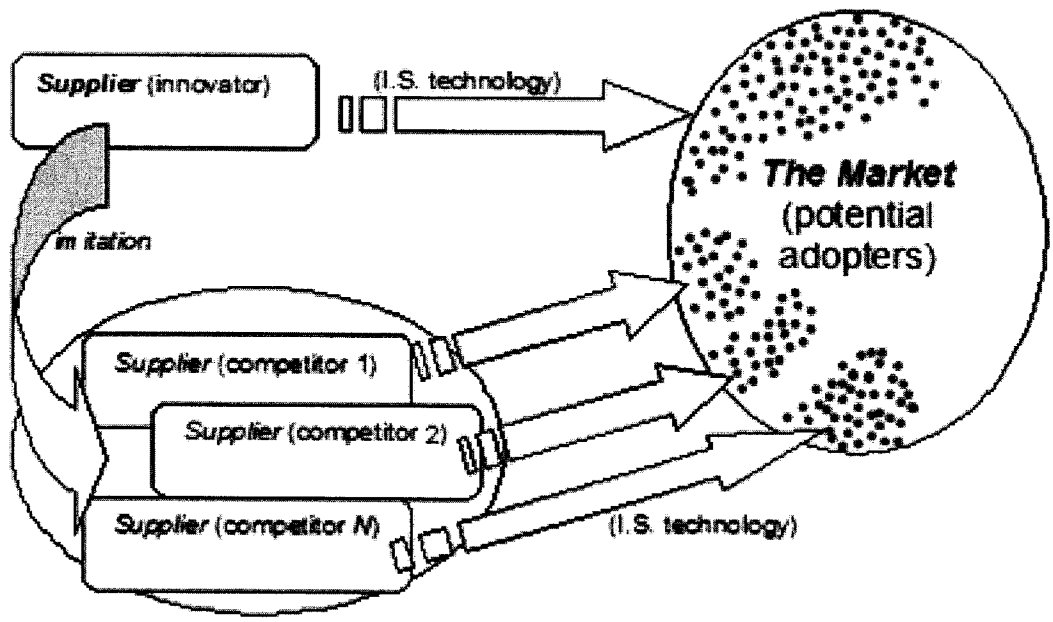
One could argue that there exists a trade off between lost profits from the direct sale of the technology and the possibility of a greater market share, enforced by lock-in induced customer loyalty. In this case, if a firm manages to establish its innovation as an industrial standard technology and gets its competitors to also produce it, whether by design or by accident, it also gains from possessing first mover's advantage, which may guarantee its technological and consequent market dominance for a lengthy time

[31] The term 'loyalty' is used here to refer to the supply-side lock-in effects of industrial standards; whereas the technology itself may be free to diffuse, imitators may need access to the innovators stock of tacit knowledge. Resulting consultancy contracts can be a substantial source of revenue (i.e. loyalty).

period. It is perhaps little wonder that firms in network industries and especially in ICT produce multiple technologies aspiring to become industrial standard technologies; examples include the contemporary competing flash memory card standards (Sony Memory Stick, XD, SD, MMC, Smart Media, Compact Flash to name but a few), distinct video compression formats (Microsoft WMV, MPEG4, DivX, Real Media, Apple QuickTime) with little or no real benefits over one another, as well as the now infamous VHS versus Betamax antagonism.

The absence of the diffusion delay caused by supply-side barriers means that the social cost associated with edge technologies does not apply and arguably, makes industrial standards a more socially desirable form of technology (Figure 2.1b). As imitation occurs, other industrial suppliers also produce the technology. Driven by increased investment in the technology and greater output, economies of scale will eventually bring the production cost down. In addition, the multiplicity of suppliers is likely to lead to increased exposure (higher observability) for the industrial standard technology thus advancing its diffusion even further.

Figure 2.1b - The diffusion path of an industrial standard (I.S.) technology

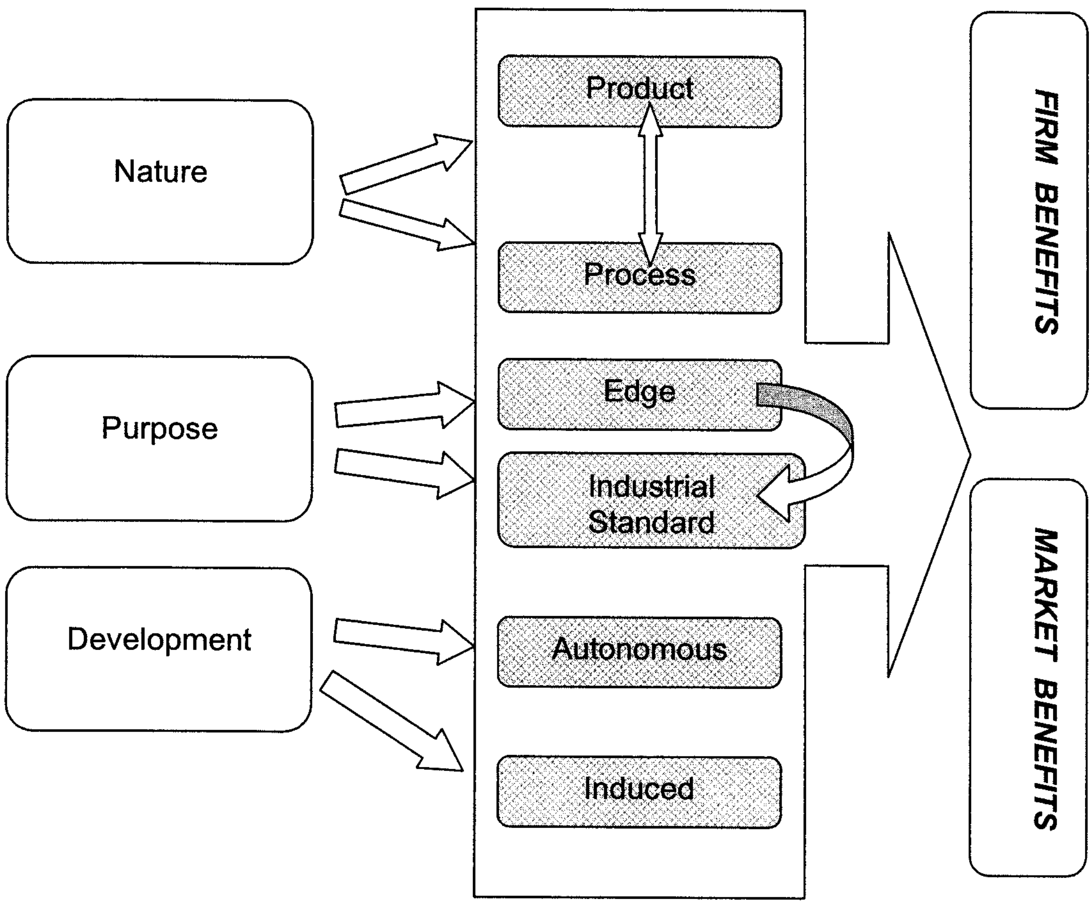


NB: dots represent adopters of a technology

In fact the single most defining feature of industrial standard technologies is that their diffusion is actually encouraged, in spite of the fact that industrial standard technologies can be marketed individually and yield an economic benefit.

In conclusion, one might categorise a technology as *product* or *process*, *autonomous* or *induced*, *edge* or *industrial standard*, intended to result in *market benefits* or *firm benefits*. The aforementioned categories are essential for an in-depth understanding of the ways technology is created, spread and utilised. They also shed further light on the normative rationale behind the development of modern innovation systems and associated policy. This complex typology of technology reflects relationships which are variably correlated, exclusive or intercomplementary. Figure 2.2 summarises this typology in terms of nature, purpose and development and thus acts as an aid to our understanding of these relationships.

Figure 2.2 - Technology: A Summary of Typology



2.5 Types of Adopters

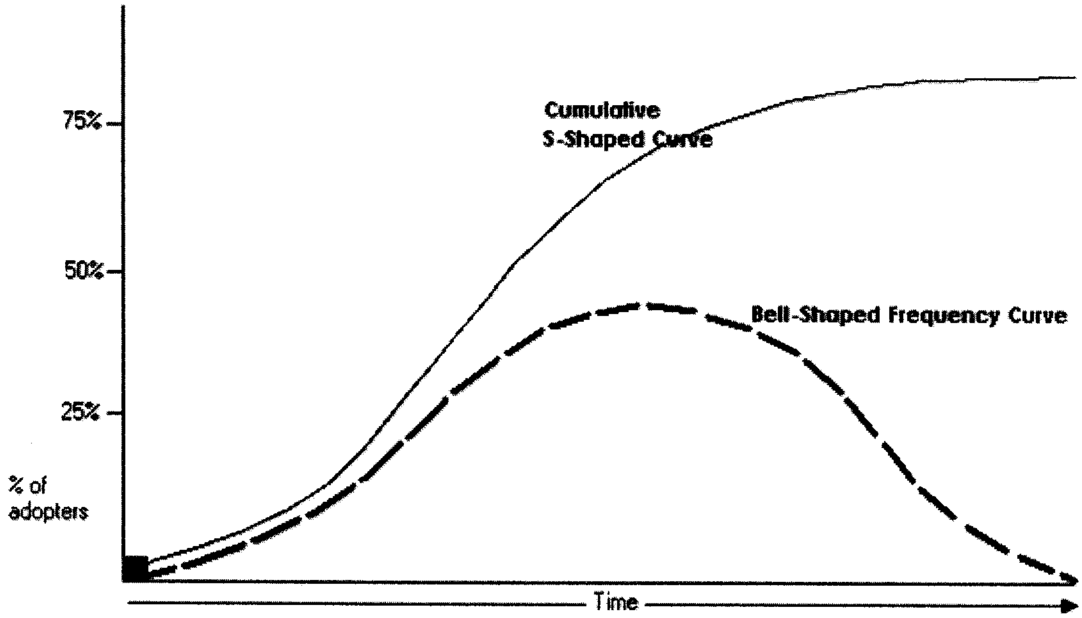
Adopter characteristics can be of significant importance in determining the intensity of use (intra-firm diffusion) and the speed of adoption (inter-firm diffusion). In their attempt to understand diffusion economists have included those characteristics as endogenous or exogenous variables in their models and found that such characteristics as the rate of sales growth, firm size and access to finance to have a varied degree of relevance. Nevertheless, it has been shown that such characteristics are often key to determining which companies will adopt a technology and which will not (Mansfield, 1961).

2.5.1 Adopter Types – (by when they adopt)

The study of diffusion is not confined to the determinants of adoption; by looking at past adoption trends diffusion theorists can get an indication of which companies are bound to embrace a certain innovation sooner than others. Rogers (1983) argues that the categorisation of adopters on the basis of innovativeness is particularly advantageous. By dividing the population of potential adopters into different conceptual groups on a gradual and sequential order from the most innovative to the least innovative it is easier to ascertain what distinguishes the firms that are successful in quick adoption from those that are not. It is a methodological technique aimed to assist our understanding of the diffusion phenomenon rather than provide clear-cut distinctions between innovators and non-innovators.

If one plots the data of the adoption of an innovation over time by the members of a social system on a cumulative basis a s-shaped curve results (Figure 2.3).

Figure 2.3 Cumulative versus S-Shaped Diffusion Curves



Both those curves represent the same data, though the bell-shaped curve shows the number of individuals adopting per time unit (e.g. a year) while the sigmoid curve shows the cumulative number of adopters. The s-shaped adopter diffusion rises slowly initially while there are few adopters for the given time period. Then its acceleration progressively increases until it reaches approximately 50 per cent when it begins decelerating as the few remaining adopters eventually take up the technology. Explanations for this slope are varied and are discussed at a later stage.

Rogers' (1983) categorisation of adopters portrays them as ideal types in accordance with their adoption time. It should be emphasised that the distinctions made are based on Rogers' (1983) majority empirical observations and as such are not to be taken literally; they were designed to be an aid to understanding adoption and chances are that in reality great deviations may be observed. It should also be noted that the proportional sizes of each group are purely theoretical. It is this way that firms are divided into five stylised sets of adopters, with respective common characteristics.

(i) *Innovators*

These adopters are keen to take risks and invest great proportions of their capital on ambitious technological projects. Therefore Rogers (1983) describes them as 'venturesome' and argues that in a typical sample they do not exceed more than 2.5 per cent of adopters. It appears though that firms which can be classified as innovators must meet a strict set of criteria. These include control of sufficient financial resources to enable them to recover in the event of an unsuccessful venture and a high degree of technical understanding prevalent among its staff.

(ii) *Early adopters*

Typically accounting for 13.5 per cent of a set of adopters they are considered high-yielding companies which can afford to take a risk. This is also determined in the industry in which they operate. Shy (2001) points out that the majority of firms in network industries are on the forefront of technological adoption and hence could be thought of as early adopters. Such firms adopt as soon as their decision making process allows them to, given that technology is an essential part of their operations. Rogers (1983) also argues that early adopters may pose as a 'model' firm for other firms considering adoption. Because they are a group of comparatively larger size than the innovators, their adoption sends a clear signal about the market 'success' of the technology; thus they facilitate greater communication with other potential adopters and they contribute to the acceleration of the diffusion process.

(iii) *Early Majority Adopters*

Typically accounting for 34 per cent of a set of adopters they adopt new ideas just before the average number of a system. Rogers (1983) argues that their adoption decision is primarily owed to strategic considerations and is the product of a lengthy deliberation process. Being the greatest of all adopter groups they send a clear signal about the market's acceptance of the technology; technologies that penetrate this group are also more likely to complete their diffusion cycle.

(iv) *Late Majority Adopters*

They typically account for 34 per cent of a set of adopters. By this stage a marginal majority of potential adopters has adopted the technology. According to Rogers (1983) adoption for this group may be dictated both by the economic reality and pressure by peers. Firms that have not adopted by this stage have lost the opportunity to take advantage of the competitive benefits yielded by early adoption. They only adopt because they are persuaded by the circumstances. A common characteristic of late majority adopters is the scarcity of resources, in both financial and human terms.

(v) *Laggards*

Usually accounting for 16 per cent of a set of adopters they are traditional businesses which are often to be found in industries that have recently experienced relatively low levels of innovation (e.g. handicrafts). The network effects of the technology mean that the need for cooperation along with recognition in the business world drive them to adopt even at this late stage. They are usually older firms, with on average older individuals in management positions (Souitaris, 2001). The scarcity of resources characteristic of late majority adopters is even more pronounced in this group. Intra-firm diffusion and adjustment is often prolonged and problematic. Rogers (1983) identifies their precarious economic position as the primary reason for their late adoption.

2.5.2 Adopter Types – (by what they adopt)

Traditionally researchers have followed Rogers' (1983) paradigm and categorise adopters according to their time of adoption. This has led to a fascination with getting adopters to adopt early and has focused attention away from some adopters who ultimately never adopt – these firms that lay above the s-shaped curve. Naturally, this brings up the question; *are these non-adopters essentially averse to adopting technology or do they exhibit a preference for certain innovations?*

An answer to this question would have to take into account the characteristics of these adopters. The suitability of a technology varies across industrial sectors, firms of different size and with distinct behavioural traits. Due to the nature of their business, or coinciding environmental factors, some firms may adopt only certain types of technology. Accordingly, the author has devised the following three conceptual categories to describe such adopters:

(i) *Mass Adopters*;

These are firms that rely heavily on technological developments in their core operational areas. The benefits yielded by technology to such firms (and their competitors) may be as great as to make the prospect of non-adoption or late adoption one that jeopardises the viability of the firm. Therefore they usually adopt a technology as soon as it is available (or soon thereafter) placing little thought on its suitability or the technology's long-term prospects. Mass adopters may also happen to be 'innovators' or even 'early adopters' and may operate in network industries (IT, banking, airlines, e-commerce).

(ii) *Product Adopters*;

Very small firms almost never adopt process technologies, possibly because they are unable to adjust their operational habits to accommodate for example a new management approach or a more efficient manufacturing process. Small companies have minimum assets and often rely on very tight liquidity margins. They rely on a small number of staff to keep the business going, meaning that a possible interruption to the flow of turnover by staff training could have a detrimental effect on their ability to meet their short-term liabilities. Hence such adopters are less likely to adopt a technology that yields firm benefits (in the internal workings of the firm) and may have greater preference for technologies resulting in market benefits. Product technologies require minimum adjustment effort and in many cases can be readily remarketed through a process of technological arbitrage. Even then, it is their perception of the *appropriability* of the technology that determines whether they do adopt.

(iii) *Opportunity Adopters*;

These are adopters that have an established operational routine that they perceive as efficient and as such, are generally adverse to any form of innovation that entails risk taking. They operate in traditional industries (agriculture, handicrafts, low-skilled services) and are complacent about the way they conduct business. Just like product adopters, they tend to have modest means but in contrast with them *cost*, not appropriability is their greater consideration. Therefore, their adoption decision is greatly influenced by opportunities arising in their business environment. Such opportunities may be the result of government policy (funding for acquisition and/or training) or may be initiated by peer pressure (demand by customers), a market imperfection (opportunity for technological arbitrage), changes in the supply chain and institutional or legal changes. In most cases the decision to adopt is almost forced upon them not by their own accord but by their external environment.

2.6 Technology Transfer

2.6.1 Types of Technology Transfer

(i) *Vertical Technology Transfer*

The flow from *basic*, or *laboratory research* through developmental stages, and ultimately to production and technology is called *vertical technology transfer*. This can represent a flow from invention to innovation to diffusion (Roman, 1983). People, organisational variances and coordination to facilitate transfer from phase to phase need to be accommodated. R&D is in general terms organised by vertical integration, since vertical technology transfer involves technological progression from science to a completed product.

(ii) *Horizontal Technology Transfer*

Horizontal transfer of technology is a far-reaching concept with wide implications for the economy. In essence, horizontal technology transfer is the transfer of established knowledge or processes from *one operational environment to another* (Roman, 1983). The operational environment may be a firm, an industry, a sector, or even a scientific discipline. It is possible for horizontal integration of research to occur through organisational methods that group scientific disciplines together. Suggesting that exclusively horizontal or vertical processes transfer technology would be an oversimplification; technology can be effectively transferred both horizontally and vertically, incorporating techniques to bridge gaps between different contexts and disciplines (Howells and Wood, 1993). This fact makes the quantification of diffusion an extremely difficult task, and advocates caution before conclusions are drawn.

Technology transfer can occur in many different environments, the varied characteristics of which directly affect both the way and the speed of the diffusion. Indicatively, according to Roman (1983) technology transfer can take place:

(a) within the organisation
(b) within an industry
(c) within the sector
(d) between industries
(e) government to government
(f) industry to government
(g) within a discipline
(h) between disciplines

Though the above mentioned diffusion levels are the main pathways through which technology diffuses, it must be noted that they are not mutually exclusive and technology transfer can occur between several different diffusion levels at the same time (Roman, 1983). For example, government-sponsored innovations intended for the military may in time diffuse into a specific industry and then in turn to other industries where the innovations may be applicable. Technological developments in avionics, communications and materials have on numerous occasions diffused concurrently in many industries. Technology, it seems, has the ability to infiltrate every aspect of human activity, a process that is further accelerated in the light of the contemporary information-intensive global economy.

2.6.2 Technology Transfer Options Available at the Firm Level

Pack (1999) analysed the different options available to firms that want to transfer technology from another organisational context to their own. He outlines two major options; the importation or local acquisition of equipment and obtaining knowledge from market transactions.

(i) Importing of Original Equipment or Purchase of Locally Produced Equipment

The purchase of equipment is a potent potential source of new technology provided that the generation of equipment purchased is more efficient (firm-benefits) than the one currently employed by the company (Pack, 1999). Importing product technologies (technological equipment yielding market benefits) is another option which is especially important for smaller firms. Market benefits can be obtained by means of technological arbitrage, that is the process of making a profit by taking advantage of the relative lack of information, is certainly possible in the niche markets that many smaller firms operate. In other words opportunities are created by the reduced technological scanning abilities (imperfect information about availability and pricing) of companies in traditional industries.

Pack (1999) points out that such gain can be obtained from both new and used equipment. In addition, according to Pack (1999) firms in technologically intensive sectors (e.g. manufacturing, or IT) have to import most of their equipment; this would be particularly true in a small country like Greece given the limited amount of innovative activity. Pack identifies economies of scale in production as the primary motivation for the importation of process technologies. However, in many cases, local firms simply do not possess the technological knowledge and/or incentives to obtain technical efficiency. At the same time, simply acquiring such technologies without a long term strategy for their assimilation and further development can prove counter productive. Critics of this approach (Jenkins, 1987; Jones, 1996) argue that importing technologies inevitably leads to a sort of technological dependency and hampers the ability of local firms to be innovative. Ultimately though, the help of other institutional actors such as governmental bodies, academia and increasingly MNEs may prove important.

(ii) Knowledge Obtained in Market Transactions

Pressure and incentives for technical change may originate in the company's trading environment. Often it may be the technology adoption decisions of customers (the so-called '*demand-pull*' effect) which exert considerable influence on a firm's technological stock. In similar fashion the technical level a firm's suppliers are in, may condition the company's technological infrastructure and operational modes (the so-called '*supply-push*' effect). It follows that the dynamics of the industry in question (its level of competition and degree of internationalisation) as well as the propensity of the firm to network and streamline operations along the supply chain are important factors. Hence firm behaviour as well as the overall stock of knowledge within an industry or more widely within a national economy is a good predictor of the technological state of the firm.

The presence of MNEs in a host country can have a strong effect on the innovative and absorptive capacity of a country (Chen, 1996; Globerman, Kokko and Sjőholm, 2000; Furman, Porter and Stern, 2002). Foreign Direct Investment (FDI) may act as a channel for the transfer of knowledge that is new to the economy under question. Pack (1999) points out that this may occur voluntarily if they permit other firms access to their technological capital (e.g. through joint ventures, or technology licensing agreements) or, involuntarily, as managers and workers leave for locally owned firms or provide knowledge in informal settings. Such transfer of tacit knowledge which is often a by-product of previous operational experience is also known as a technological 'spillover'.

In cases where horizontal technology transfer occurs, the presence of MNEs can affect the structure, behaviour and performance of firms in the host economy. As Chen (1996) points out there are three possible ways for spillovers to occur. First, foreign affiliates may distort the intensity of local competition levels because multinationals are usually better equipped to overcome entry-barriers. Second, the training and education of the employees of a foreign affiliate could become available to the market as a whole or to the economy in general. Third, the presence of MNEs may force local firms to pay greater attention to the technology element and speed up their adoption of new technologies.

Chen (1996) also points to research[32] indicating that foreign affiliates are more likely to demonstrate higher productivity levels than local firms. A study by Blomström and Sjőholm (1998) suggests that spillovers from foreign direct investment (FDI) may occur from increased competition and labour turnover, or through demonstration, and can take place either in the foreign affiliate's own industry or among the affiliate's suppliers and customers in other industries. The effects of the technological spillover depend to a large extent on host country and host industry characteristics and the policy environment in which the multinationals operate. Studies on the subject have produced mixed results and have shown that spillovers are subject to the presence of conducive conditions. Until recently it was believed that the degree of local participation (i.e. ownership sharing) in foreign affiliates has a direct effect on the extent of technological diffusion. This way the MNEs proprietary knowledge is revealed and spillovers are facilitated. However, a study by Blomstrőm and Sjőholm, (1998) entitled "*Technology Transfers and Spillovers: Does Local Participation with Multinationals Matter?*" dismisses such an assumption as invalid using evidence from a survey in Indonesia. Blomstrőm and Sjőholm (1998) maintain that forcing multinationals into equity sharing can cause problems. For example, if there is a risk for foreign firms to lose their intangible assets to a local partner, they may either refuse to invest or bring less advanced technologies to the affiliates.

[32] Refers to empirical data from firms in Mexico compiled and analysed by Blomstrőm and Persson (1983).

Furthermore, Jones (1996) casts further doubt on the effect of spillovers. He argues that such an effect is minimised by the fact that MNEs undertake the bulk of their technological development activities in their home countries. More specifically Blomström and Sjöholm (1998) suggest that spillovers may not materialise if the technology gap between foreign and local firms is too large, because then there may be little scope for learning. Indeed, this assumption is reinforced by the findings of Haddad and Harrison[33] (1993).

It is also possible for a spillover to occur as a result of vertical technology transfer. When a MNE affiliate enters the market of the host country it has to decide on foreign or local sourcing, making or buying inputs locally and the kind of relationship it will develop with suppliers of the host economy (Chen, 1996). The technological capabilities of host economy suppliers will be boosted either through a learning effect (observation and imitation of products, services, procedures) or the actual technological hardware passed on to them.

2.6.3 The Product Cycle Theory on International Technology Transfer

The spread of technology across national boundaries is often referred to as 'international technology transfer'. A recurring theme in the study of international or cross-country technology transfer is the potential effect it may have in terms of economic development. The majority of development economists agree that the

[33] Haddad and Harrison (1993) in their research of Moroccan firms found no significant instances of technological spillovers and attributed them to low levels of competition and problems relating to communication.

importance of technology for economic growth is pivotal. Romer (1986, 1990 and 2000), for instance in his studies of economic growth characterised technology as one of the major 'factors of production'[34] (along with labour and capital). As a result, most studies on technology transfer are less concerned with the process itself (the paths it takes and the factors affecting adoption); they are rather interested in its consequences (whether they are its impact on employment, standards of living or economic growth). Nevertheless, a brief outline of conclusions drawn in technology transfer literature will aid our understanding of established channels and allow us to draw parallelisms between cross-boundary technology transfer and technology diffusion across firms.

Vernon (1966) analysed the international diffusion of technology under the context of the "*product cycle*" theory. The product cycle theory is an important contribution towards an explanation of the internationalisation of technology and the process of technology transfer. The model's interest lies in the link it forges between the diffusion of an innovation and the location decisions of MNEs. According to the model, most innovations are labour saving. Process innovations substitute capital for labour or reduce input requirements for labour more than they do for capital. Product innovations such as household durable goods substitute capital for labour in the production utility within the household. Therefore, *the value of such innovations is greater in countries where wages are highest relative to the cost of capital.* Invention

[34] Early growth economists (Ricardo) identified the factors of production as *land, labour, capital* and *enterprise.* They argued that growth in a country's GDP was largely connected to rises in these factors of production. Contemporary development economics advocates that the first one (land) is largely irrelevant in the modern world and the fourth one has expanded to include technical innovations and ideas and is referred to as 'technology'.

is described as an economic search process driven partly by the inventor's perception of how value can be created. The inventor is more prone to influences from his/her immediate environment; hence inventions are more likely to originate in high-income countries. Initially, production is concentrated in these countries and methods of producing the new innovation are fluid and small scale. Vernon (1966) argues that uncertainty about optimal production methods and configurations of the innovation discourages both the development of large-scale production and worldwide search for the most efficient production location.

Eventually use of the new technology spreads to other countries as they experience rising real wages (and values of household labour time) making saving labour more profitable and as the real price of the innovation falls. As the innovation's technology and production method stabilise, a search intensifies for low-cost production locations, and this search tends to carry production to lower wage countries. Increasing price elasticities of demand, as users grow more familiar with the innovation, and increasing competition in the product market pull in the same direction. Then expanding production in other industrial countries displaces exports from the high-income innovating countries. Finally, as the innovation matures, the shifting pattern of production and use might ultimately carry production to the developing countries, with the industrial countries losing their comparative advantage, but it is a common occurrence that the mature innovation is displaced by its successor before this final stage is reached. The product cycle theory of trade and investment hinges on the international diffusion of new technologies and new products.

Vernon's contribution is also significant towards an explanation for international diffusion inequalities. According to the product cycle theory, diffusion is essentially a developmental process. Diffusion, just as innovation, is motivated largely by profit and firms will adopt motivated by a desire to cut down wage costs. As a country develops and the cost-effectiveness of local labour declines, MNEs increasingly rely on the transfer of technology to remain competitive. In the long run and as the host country develops a domestic market of considerable volume, simple technology transfer is no longer adequate. Subtle or substantial innovation is required by MNE subsidiaries who appeal to these mature markets.

Vernon's (1966) theory is paramount to understanding the technological competencies of economies in transition. As such the product cycle framework could prove useful in directing technology policy. Nevertheless, the product cycle theory is more pertinent at a macro-level as it does not explain variations in adoption within an economy. At the same time, the product cycle is less relevant in the context of an information economy; its insistence on the labour saving qualities of technology means that it fails to account for the market-related opportunities offered by modern ICTs.

2.6.4 Other Theories on the International Transfer of Technology

Other theories proposed at the macroeconomic level include the so-called '*internalisation*' theory (emphasising neoclassical assumptions about the importance of enterprises in increasing the size of the economy) and the so-called '*Global Reach*' approach. Both theories are in essence attempts to explain the influence of MNEs, the former seeing them as positive actors while the latter being rather sceptical.

According to Jones (1996) internalisation theory emphasises on MNEs as a mechanism for overcoming imperfections in external markets and identifies the market for information as a crucial one in which there are strong incentives to internalise due to the nature of technology as a public good. The internalisation theory predicts that MNEs are particularly likely to be found in R&D intensive industries. Therefore, developing countries can only benefit from the presence of MNEs in their economies, since they will prepare the grounds for the establishment of R&D intensive industries.

The Global Reach approach is diametrically different in that it perceives the control of technology as one of the most crucial monopolistic advantages of MNEs as they expand internationally (Jenkins, 1987). Marxist theorists have also stressed the importance of technology in relation to development in the Third World. Emmanuel (1982; cited in Jenkins, 1987) believes that the introduction of advanced technology by MNEs is a major contribution to the development of the Third World. Jenkins (1987) deems that Emmanuel directly contradicts the more conventional emphasis of

Marxists on 'technological dependence' as a major element in the subordinate position of Third World countries in the world economy and the identification of the latest stage in the relationship between them and the advanced industrialised countries as 'technological-industrial dependence'.

According to neoclassical theory on technology when faced with different factor prices (due to differences in factor endowments), agents will typically adopt different techniques in different countries. Thus the real question is whether agents in different countries can access the global pool of technologies at *the same cost.* Parente and Prescott (1994) have emphasised barriers to technology adoption as a key determinant of differences in per capita income across countries. In their model, while any firm can access the underlying stock of knowledge in the world economy, the cost of such access may differ across countries due to differences in legal, regulatory, political, and social factors. Thus the argument is that some countries make it inherently costlier for their firms to adopt modern technologies and thereby retard the development of the entire economy. In fact, Parente and Prescott (1994) go on to suggest that trade may affect growth by lowering the barriers to technology adoption.

However, the bulk of neoclassical theory on technology concentrates on the impact of R&D, the incentives behind it and the effects on the host economy. Romer (1990), Aghion and Howitt (1990), and Segerstrom, Anant and Dinopoulos (1991) were among the pioneers of R&D based models of economic growth. While they differ from each other in important ways, one underlying idea common to these models is that entrepreneurs conduct R&D to gain temporary monopoly power where such a privilege is made possible due to the provision of intellectual property rights. The temporary monopoly lasts only until the technology is copied, reverse-engineered or at best until the patent expires.

Finally, the country-specific characteristics of the host economy need to be considered when faced with issues of technology transfer. High illiteracy rates, undeveloped infrastructures, alien business cultures, legal complexity and high corruption are considerable obstacles to the transfer of latest technologies. Even when technology transfer does happen, its results are not guaranteed to be positive. A study by Brown (1979; cited in Jones, 1996) explaining the reasons why the transfer of technology did not lead to development in China during the 1970s, found that that the country's system of political economy and the attitudes of its officials were major obstacles. Country-specific characteristics often account for differences in vertical technology transfer across countries. In particular the speed of diffusion or assimilation of new technologies is often found to be different. It is by measuring the speed of diffusion during its distinct stages and modelling the decision to adopt that one can reach conclusions regarding its facilitators and inhibitors.

2.7 Technology and Culture

The impact of different cultures on economic activity is a highly controversial subject. There is little economists agree on when it comes to culture and this is largely why it is a topic largely ignored by literature on economics. In addition, the very real problem of accurately defining it as distinct from other social trends has made measuring its impact extremely hard and relegated it into a 'residual' for most considerations.

Most economists see society as a set of functional mechanisms and think of culture as the historical consequence of these mechanisms and external influences, rather than an inherent characteristic of society. They see culture as something that can be moulded and altered as a result of changing circumstances. Indeed, a study seeking a link between technology and culture defined culture as '*the servant of technology*' (Youngs, 1997). Surely though, when one compares societies in an international context and for defined time periods those characteristics which do not fall under the functionalist assumptions of rationality and structural causality, inevitably will be attributed to some sort of residual one could gracelessly refer to as 'culture'.

In the post-Cold war era, technology has been identified as the single defining power, in terms of international politics, economics and ultimately culture. Francis Fukuyama (1992) predicts that over time the spread of technology and its enabling qualities will produce a homogenised, equal world stage where national cultures are nullified. Fukuyama's goes as far as to suggest that this cultural and ideological equilibrium will favour the emergence of a new 'global culture' which shares the belief that technological progress should be the centrepoint of human endeavours. Youngs (1997) argues that technology and culture are fundamentally opposing forces; culture has clearly defined, often national boundaries, whereas technology enjoys an influence that is transnational. Youngs (1997) agrees with Fukuyama in that technology is gradually eroding the influence of culture in societies across the globe.

This friction though, has inevitably resulted in a backlash; in response to the threat posed by the forces of globalisation (forces fuelled to an extent by technology) many national cultures have been stubbornly resisting the overwhelming force of change (Friedman, 2000). This is often done by exaggerating cultural characteristics and is a process frequently motivated by people who see no role for themselves in the new realities as they are defined by technology. Friedman's widely popular work '*The Lexus and the Olive Tree*' (Friedman, 2000) portrays the friction between these opposing forces in the sharp contrast of two highly symbolic images; that of a highly technologically advanced car production facility set up by Lexus in Japan on one hand, and the raging conflict over 'olive trees' in the Middle East on the other. The uneven spread of supposedly 'global' values indicates that ideology and philosophy about life as they translate in culture are still very much relevant and merit special analysis.

Different cultures influence the technological competence of an economy, both directly and indirectly;

- *Directly*: A cultural mentality that is isolationist, inward looking, risk averse and apprehensive towards change could for instance affect management decisions with regards to adoption.
- *Indirectly*: Culture can have an impact on the structure of the economy, the size, nature and expectations of the labour force and the transparency and effectiveness of its political and legal systems.

Kennedy (1993, cited in Youngs, 1997) demonstrates the indirect effect culture can have in the assimilation of new technology by pointing to the problem of Africa's demographic explosion. Kennedy argues, traditional African cultural beliefs concerning fecundity, children, ancestors and the role of women in the society have triggered a population boom with detrimental effects on the economy; unemployment, poverty and limited access to education and healthcare.

A number of studies have tried to categorise and model cultural traits which can have an effect on general economic performance, particularly with regards to economic development (Thompson, 2001). According to Thompson (2001) the relationship between 'culture' and 'economic development' in research during the past fifty years has been viewed variably as causal, correlative or relatively autonomous. Thompson (2001) argues that culture could only have an impact on economic processes when taken into its historic context. He dismisses attempts to study culture in isolation from other factors as too simplistic.

On a micro-scale, the most widely recognised categorisation of national cultures with relation to organisational structure and management attitudes is that initially devised by Geert Hofstede (1985). Hofstede's study involved questioning 116,000 IBM employees in forty different countries about their perceptions and preferences in terms of management style and work environment. Hofstede (1985) describes national cultures in term of four dimensions:

- ***Power Distance,*** that is the extent to which the members of a society accept that power in institutions and organizations is distributed unequally.
- ***Uncertainty Avoidance***, that is the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity, which leads them to support beliefs promising certainty and to maintain institutions protecting conformity.
- ***Individualism***, which stands for a preference for a loosely knit social framework in society in which individuals are supposed to take care of themselves and their immediate families only; as opposed to ***Collectivism***, which stands for a preference for a tightly knit social framework in which individuals can expect their relatives, clan, or other in-group to look after them, in exchange for unquestioning loyalty.
- ***Masculinity***, which stands for a preference for achievement, heroism, assertiveness, and material success; as opposed to Femininity, which stands for a preference for relationships, modesty, caring for the weak, and the quality of life. In a masculine society even the women prefer assertiveness (at least in men); in a feminine society, even the men prefer modesty.

The above dimensions have been criticised for being too simple (McSweeny, 2002), too broad and difficult to model into meaningful relationships (Royer and van der Velden, 2002). McSweeny (2002) argues that the reason for the success of Hofstede's ideas lies not with their scientific validity but with the appeal these ideas have had at higher levels of management. In turn, McSweeny (2002) points out that this appeal comes down to the simplicity and conciseness of Hofstede's dimensions. In other words it is because managers could easily understand and act upon Hofstede's ideas that they became popular. This is despite serious conceptual shortcomings; for example Hofstede's theory does not allow for variation within national culture or changes over time. In addition, it makes the bold assumption that a single empirical study is enough to devise a thorough typology of culture. In Hofstede's defence, Royer and van der Velden (2002) point to Hofstede's relatively large sample size (116,000).

In conclusion, the element of culture whether at a micro- or macro-scale has been the subject of a great deal of controversy. There are good arguments for and against its validity. Therefore, one ought to be cautious when referring to culture and should perhaps only use it to complement already established arguments. This is why in the present study, culture is studied in conjunction with other factors and no attempt is made to quantify and directly model its influence in isolation. Rather culture is taken into consideration by proxy; where assumptions are made about economic and behavioural factors influencing diffusion the author cautiously draws upon cultural theory as a means of corroboration. Indeed so blurred is the distinction between culture and other factors influencing human behaviour that it may be best to treat culture as an historical imprint of economic, social, political and even psychological factors; an echo of people's not too distant collective past. Just like a sound echo, one may argue that culture probably fades away with time – especially when new prevailing ideas, technologies and attitudes overwhelm it.

2.8 Conclusion

Chapter 2 presented a bird's eye view of the historical development of an economic understanding of innovation and diffusion. A brief introduction to the rationale and dimensions of official policy directed at improving technological performance was also provided. The basic interactions between technology and the economy were outlined with an emphasis on innovation's microeconomic effects and industrial dynamics. These relationships are crucial to an effective understanding of the mechanisms driving the innovation process. They also provide an initial insight into those characteristics of individual innovations that are important for diffusion.

The understanding of the interface points between technology and the economy is further advanced by an analysis of the different types of technology. Importantly, the author contributed new types of technology and technology adopters, thus providing useful analytical tools for explaining observable instances of diffusion employed in later chapters. Moreover, the author compiled a section on the major theoretical contributions on the motivations and implications of the transfer of technology both internationally and across industries and firms. Finally, a brief exploration of the influence of national cultures on the creation and diffusion of innovations is provided. In this the author identifies the methodological difficulties associated with the analysis of the concept of 'culture' and concludes that its influence can be best ascertained qualitatively.

The above inform the broad understanding of relationships between innovation and the economy and as such, permit one to progress to a more thorough analysis of the mechanisms for the communication and spread of technologies; the following chapter deals with systematic attempts to measure, model and explain the diffusion process.

Chapter 3 - Economic Theory on Diffusion

The investigation of the truth is in one way hard, in another easy ... no one is able to attain the truth adequately, while, no one fails entirely, but everyone says something true about the nature of things, and while individually they contribute little or nothing to the truth, by the union of all, a considerable amount is amassed

Aristotle, *Metaphysics*

3.1 Measuring Diffusion

General observations of economic relationships and qualitative documentary analysis can lead to the deduction of useful propositions or theories; indeed this is the manner that progress is achieved in our understanding of economics. The need to add credibility to any viable proposition is fulfilled by the utilisation of quantitative data and their analysis. Therefore, accurate measurement not simply of absolute sizes, but also of relative weights is extremely important.

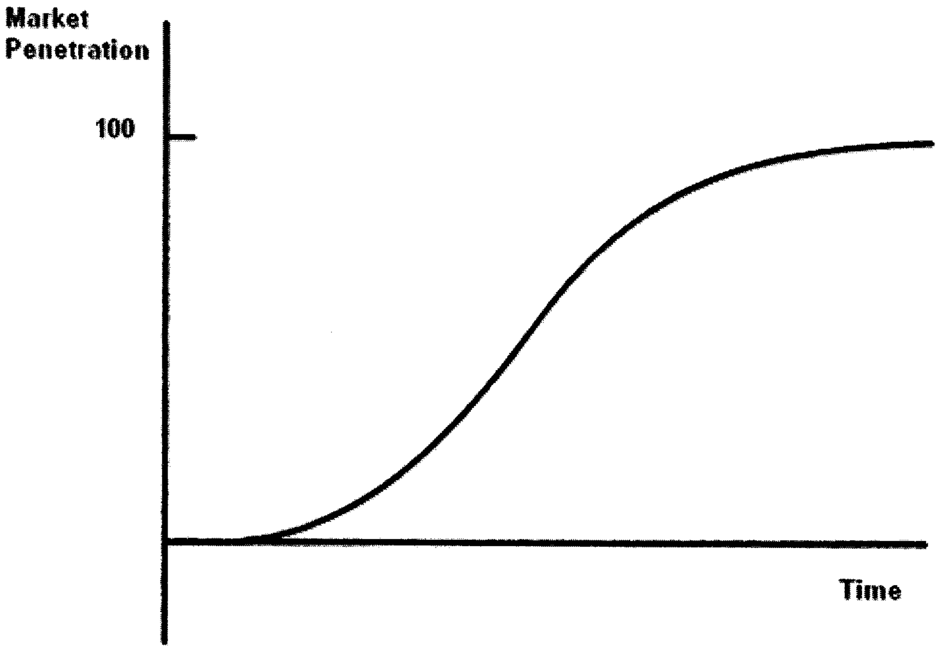
There are a number of ways in which the diffusion of a technology at any particular time can be measured: the proportion of firms in the industry that use it, or the share of output, capacity or employment which it accounts for in relation to the industry's total output, capacity, or employment (Nasbeth and Ray, 1974; Shepherd, 1990).

The first, the number of companies which have adopted the new technology, only measures diffusion among firms, while the others measure diffusion both among firms and within firms, though in different ways. The method of measuring the proportion of firms in the industry that use it, has the advantage of been practically easy to calculate with a high degree of reliability. Nasbeth and Ray (1974) argue though that for a number of purposes other measures are needed.

In assessing the impact of new technology on productivity for instance, the proportion of output it accounts for is a crucial factor. More than often, the denominator in this fraction (the potential area of application of the new technology) is difficult or impossible to define in a precise manner. In some cases a new technique may be successfully applied to a whole industry, whose limits are easy to define, but there are also many techniques which are only suitable for application, at least in their early stages, to a certain type of production within an industry. Then it is necessary to decide whether to take as the relevant total production that of the whole industry, or only of that part of the industry for which the technique is appropriate/suitable. Due to the fact that it is often impossible to determine the appropriability/suitability of a technology, the relevant total production is more frequently chosen.

The ultimate diffusion measure is the speed by which the technology gets adopted by firms. From a competitive perspective, technologies that diffuse relatively fast are usually the most successful in dominating the market, having had the advantage of an early market entry. The measure of speed itself however is not as important as the conclusions one can draw from it. Measuring the speed of diffusion has attracted a considerable volume of research on the subject as how fast a technology diffuses can give us an insight to the *actual factors determining its adoption*. Traditionally researchers have visualised the speed by which a specific technology diffuses among a group of pre-defined adopters by plotting the technology's market penetration over time. As mentioned before, it is a common finding amongst researchers that the resulting diffusion curve is sigmoid or S-shaped (Figure 3.1).

Figure 3.1 – The Diffusion Curve



In simple terms this can be explained as follows; initially the take-up rate of a technology is slow, as few of the potential adopters are aware of the availability of the technology. As more and more firms begin using the innovation and the success of its qualities becomes increasingly apparent, the adoption rate accelerates. It finally peaks when the majority of potential adopters have implemented the technology.

Knowing how quickly a technology was diffusing at any given time and relating changes in this rate to characteristics of the firm or the industry, characteristics of the technology and strategic considerations allows us not only to identify the key factors for adoption but also to assess their relative weight at varying circumstances. For relatively short periods of time it is the adoption event itself (whether adoption occurs at all) that is important. For instance, firm size may be an important factor for the adoption of a technology in the banking sector (see Gourlay, 1998, 2000) but the importance of firm size may be not be as great for a technology in the computer software industry[35]. At the same time, cross-country studies have identified country-specific characteristics affecting diffusion. Caselli and Coleman (2001) investigated the diffusion of computers across a set of countries; they found that factors like education (human capital), infrastructure, a large manufacturing sector and trade openness act as catalysts while a large public sector prevents diffusion.

Other theorists have attributed changes in the speed of adoption to the different inherent characteristics of firms and the subsequent varying yields they can expect from the adoption of a technology (known as rank effects). A number of different hypotheses have been made and translated into corresponding models which include epidemic models, equilibrium or rank models (probit/logit), game theoretic models and evolutionary models. Diffusion researchers such as Griliches (1957), Mansfield (1968), Metcalfe (1981), Rogers (1983), Stoneman (1976, 1983, 1995) and others conducted empirical research measuring the speed of adoption, instances of adoption, or both, in an attempt to verify their propositions. The present chapter presents an attempt to analyse the results of such studies with a view to constructing a theoretical framework of diffusion.

[35] Technology in the software industry usually evolves through process innovation (i.e. programming languages) which are of relatively low cost in relation to their labour-saving value, thus the adoption cost is low (on a number of occasions the technology may be freely available, as is the case with open source GPL software) and only a small number of employees is capable of delivering a profitable product.

3.2 The Determinants of Diffusion; Attributes of technologies

It is immediately obvious that a uniform theory explaining the mechanisms behind technological diffusion would be immensely complex due to the fact that not all technologies are equivalent units of analysis. As is apparent from the definition of new technology supplied earlier (see §1.1), each technology has varying attributes or characteristics, which may ultimately determine its success in spreading to all the potential adopters and affect the speed by which it does so. Everett Rogers (1983) systematically categorised such attributes and divided them under five headings; relative advantage, compatibility, complexity, trialability and observability.

(a) *Relative Advantage* is the degree to which an innovation is perceived as better than the idea/product/process it is about to replace. For instance, when a firm considers the introduction of a new technology, the relative advantage may be the perceived potential profitability from the technology weighted against the profitability of the technology the firm uses at the time and the cost of implementation. In economic terms the relative advantage of a technology may take the form of cost-cutting (economising on resources or acting as a substitute for expensive labour) or performance enhancing (resulting in productivity rises). This performance rise will usually take a different form for different industries and technologies, which makes comparisons difficult. What complicates matters more, as Rogers (1983) points out, is that the relative advantage of an innovation may be measured not only in economic terms, but also in social/prestige factors, which often exert considerable influence on the decision to adopt. Measuring the relative advantage of an innovation can be problematic as profitability resulting from the adoption of a specific technology is in many cases impossible to distinguish. Hence, studies often measure the perceived relative advantage – as it is perceived by decision making agents (Davis, 1989; Carter and Belanger, 2003).

(b) *Compatibility.* The compatibility attribute refers to the degree to which an innovation is perceived as being compatible with existing tools, machinery and processes. Moreover, it denotes the degree to which the technology is consistent with the values, past experiences and needs of potential adopters (Rogers, 1983) but also the degree to which it complements and extends the abilities of existing technologies. As such, it also often used to denote complementary qualities that a technology may have. The adoption of an incompatible innovation often requires the prior adoption of a new value system.

(c) *Complexity.* When describing a characteristic of a technology, the term refers to how difficult it is for a technology to be understood and used (Rogers, 1983). Some innovations are easily understood by the majority of the set of potential adopters. Often, as a result of high complexity some technologies will be slower to diffuse or may not diffuse at all. However, as with all other attributes of technologies, complexity is a perceived value and is highly dependent on the experience, background and education of the social context it is intended for (Davis, 1989).

(d) *Trialability.* This is the degree to which an innovation may be experimented for trial purposes on a limited basis (Rogers, 1983). New ideas that can be tried partially have been found to diffuse faster than innovations that are not divisible. Getting a taste of the new technology provides potential adopters with the chance to directly assess its relative advantage, compatibility, complexity and complementarity and thus alleviate inhibitions. As Ryan and Gross (1943) note in their survey-based research on the diffusion of hybrid corn in the United States farming industry, all of the respondents that had adopted hybrid corn had first tried it on a partial basis.

(e) *Observability.* Rogers (1983), defines observability of a technology as the degree to which the results of an innovation are visible to others. The higher the observability of a given technology, the more likely it is that diffusion of information will occur quickly and the potential adopters will begin considering implementation. Rogers (1983) provides an example; solar panels on a household's roof are highly observable and a California survey (cited in Rogers, 1983) found that the typical solar panel adopter demonstrated his equipment to about six of his peers. Observability is not confined in first-hand observation but is used to describe the technology's ability to advertise its qualities through the various communication channels.

(f) To the above characteristics categorised by Rogers (1983) the author opts to add the *life expectancy* of a technology. Since innovation and the evolution of human knowledge is a never-ending process one can safely assume that all technologies eventually complete their life cycle, giving their place to newer innovations. The scientific field and industry this technology was conceived in and aimed at largely determines what the life expectancy of a technology would be, because different scientific fields experience varying rates of technical change. The life expectancy of a

technology has received surprisingly little attention in the literature (with the possible exception of evolutionary economics), probably because until relatively recently in most sectors, the rate at which new technologies superseded older ones had been low. However, breakthroughs in computing in the early 1970s and more specifically in the development of semi-conductors (microchips) caused unprecedented rates of technical change. As a consequence new technologies replaced older ones in a faster rate than ever, affecting technologies not only in the field of computing but also in associated fields such as communications and other areas of inquiry massively benefiting by quick and convenient accessibility to information. It was this rapid pace that in 1965 prompted IBM's director, Gordon Moore, to come up with what came to be known as "Moore's Law". The so-called Moore's Law dictates that the density of transistors on integrated circuits doubles every eighteen months[36]. To this day Moore's largely arbitrary prediction has proved mostly accurate. Adopting a technology with such short lifespan calls for serious consideration.

On a number of occasions a firm's decision to adopt a new technology and invest not only in the cost of acquiring it but in adapting its existing structures to it, would be greatly influenced by the technology's life expectancy (or at least its perceived life expectancy). In a technological environment where the rate of technical change is as high as in computing (communication technologies, biotechnology), the perceived 'expiry date' of an innovation product or process is of paramount importance. A firm's

[36] Such a fast pace of change is unparalleled in any other field as the following anecdotal quote vividly describes; "*The way Moore's Law occurs in computing is really unprecedented in other walks of life. If the Boeing 747 obeyed Moore's Law, it would travel a million miles an hour, it would be shrunken down in size, and a trip from London to New York would cost about five dollars.*" Source: Wired.com, 3/9/1995

decision to implement a new technology is partly conditional to the perceived relative advantage for the duration of the technology's life cycle being greater than the cost of adopting.

(g) Finally, the author proposes that a previous experience or the *success of implementation*[37] of a similar technology in the past could influence the decision to adopt. Many organisations may have had negative experiences with the implementation of certain technologies; they often face a situation where the initial estimation of the technology's relative advantage may have been exaggerated and they later find that the positive gains they are experiencing from this technology hardly justify the investment. One such example is the under-utilisation of ICT in educational institutions often cited in OFSTED[38] inspectors' reports in the UK. Educational institutions, which fail to embed ICT effectively in their operational and educational activities, are less likely to invest in new ICT equipment. According to OFSTED (2002: 25), only schools that have been successful in delivering classes using electronic aids were investing in the latest wireless networks.

Conversely, a successful previous experience can encourage the adoption of a similar technology, especially one with a higher relative advantage. Existing literature has highlighted the importance of learning effects (Arvanitis and Hollenstein, 2001; Hollenstein, 2001); when a firm adopts a certain type of technology, cumulative learning by doing could facilitate the adoption of other similar technologies. Colombo

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[37] Such success may translate to an increase in profits, reduction in costs, efficiency and convenience, i.e. either market or firm benefits.
[38] Office for Standards in Education (OFSTED), A British government agency in charge of regulating the education sector whilst assessing the performance of individual institutions.

and Mosconi (1995) argue that this is especially true among technologies which complement each other (or may be described as "sequential"), but also in the successful implementation of vintage technologies. The following table (Table 3.1) provides an indication of the broad acceptance that each of Rogers' determinants enjoys in academic publications. It appears to indicate that the relative advantage (as opposed to the cost of implementation) of a technology is the most widely studied factor which also enjoys a relatively high degree of acceptance. Positive correlation between diffusion and the degree of observability, compatibility and the trialability of a technology is suggested by the majority of studies. However, the existence of such a correlation is somewhat more ambiguous for the factor of complexity.

Table 3.1 – Studies Supporting the Validity of Selected Determinants of Diffusion

Generalisation	Support of the Generalisation (number of research studies) Supporting	Non-supporting	Percentage of research studies supporting the generalisation
(a) The ***relative advantage*** of an innovation as perceived by members of a social system, is positively related to its rate of adoption	**33***	**14**	**70***
(b) The ***compatibility*** of an innovation, as perceived by members of a social system is positively related to its rate of adoption	**21***	**9***	**70***
(c) The ***complexity*** of an innovation as perceived by members of a social system is negatively related to its rate of adoption	**10***	**8***	**55***
(d) The ***trialability*** of an innovation as perceived by members of a social system is positively related to its rate of adoption	**13***	**4**	**76***
(e) The ***observability*** of an innovation as perceived by members of a social system is positively related to its rate of adoption	**7**	**2**	**78**

Source: Rogers (1983: 239), (*) updated in 2005

All the above factors have one thing in common; they are difficult and in some cases even impossible to quantify and therefore to model into direct economic relationships. To this end, a mixture of perceived and actual values is usually employed. Although an effort is made to understand the influence of as many of them as accurately as possible the complexity and measurability of each aspect should be taken into account when assessing empirical findings.

All the attributes of individual innovations mentioned above do influence directly the perceived appropriability and profitability of a technology so they are ultimately significant factors in the decision to adopt. However, a number of contextual factors may also hinder or facilitate the firm's ability to adopt a technology.

3.3 The Determinants of Diffusion; Non Technology Specific Factors

3.3.1 Firm- and Environment- Specific factors

Individual technology attributes, important though they are, do not solely explain the workings of the diffusion process, nor its path and speed. The diffusion of a given technology is a rather complex process determined by a number of both endogenous and exogenous factors (see §3.1).

First of all, the *size and structure* of the organisation considerably influences the speed of adoption of an innovation. Large firms may for a variety of economic, technological or other reasons behave differently from medium-sized or small firms. Small and medium enterprises (SMEs) in particular tend to be risk-averse and avoid investing in a technology until its market potential and general efficiency yields have been proven. SMEs often specialise in markets where innovation is less important, as for example in the retail industry. Added to that, for the vast majority of SMEs maximising company growth is not the highest priority, particularly when it involves taking risks; maintaining their current market share and providing employment to its workforce may be more important especially since many of them are family owned and tend to associate growth with loss of control over management. Research on the technology adoption decisions of SMEs indicates that the *lack of sources of finance* is a major factor hindering technology adoption (Cobham, 1999).

Moreover, large organisations are more likely to engage themselves in R&D activity and as a consequence have better knowledge of the market for technologies. Large firms usually have correspondingly large resources available at their disposal. Thus, they can benefit from economies of scale in the acquisition of information on new innovations and their effective implementation. Large sized firms, particularly MNEs, tend to have large specialised departments dedicated to market research and analysis of the competitive and economic environment which continuously identify potential opportunities for product or process differentiation through innovation. MNEs have elevated this activity into one of their sources of competitive advantage and are partially motivated by what is seen as technological opportunism (Ethier and Markusen, 1991). As discussed previously, MNEs are the primary actors in the international transfer of technologies. Much of their investment in any given market is placed on innovations and the global competition that they face often contributes to their willingness to innovate.

Empirical studies (Mansfield, 1964; Nelson, 1962; Nasbeth and Ray, 1974; Metcalfe, 1981; Stoneman, 1983; Antonelli, 1985) have indicated that the organisation and structure of the industry, in addition to that of the firms[39] can affect diffusion to a great extent and may account for differences across different countries. High concentration or a monopoly position can create conditions which may influence diffusion (Nasbeth and Ray, 1974). The level of *competition* in an industry is also a very important consideration. Firms competing for a larger share in a market strive to diversify and differentiate themselves from competition in any way possible. Product or service innovation can help companies increase quality, reduce costs and ultimately achieve a better position in relation to competitors. It is not a coincidence that highly competitive industries are often technologically intensive; indeed innovation is thought to be one of the main sources of competitive advantage (Porter, 1985). Porter's theory of competitive advantage proposes that companies innovate in order to outdo their competitors by providing a differentiated product or service. One could go as far as suggesting that the steady outflow of innovations is actually a characteristic feature of competitive industries. Firms operating in such an environment are bound to be less hesitant in adopting new technologies; information diffusion should occur much faster in such markets as the viability of the firms operation depends on its ability to quickly assimilate innovations. At the same time, the opposite is true; the rapid pace of progress and concentrated innovative activity in an industry actually foster competition. Firms which operate in innovation-intensive industries (such as ICT, aerospace, biomedicine) face stiff competition triggered by innovations. Companies in such industries also tend to be less risk-averse; gambling

[39] As Nasbeth and Ray (1974) have pointed out, the level of diffusion can be influenced through foreign associations, or the vertical or horizontal integration of companies within a holding company

on the success of upcoming product or service innovations is part of their business practice[40].

In addition, a crucial factor is the availability of *finance* to cover the cost of the adoption (Rogers, 1983; Stoneman, 1995; Gourlay, 1998; Cobham, 1999). Such cost includes not only purchasing the technology (by licensing a patent, or buying the physical hardware) but also adjusting existing structures to it (staff training, upgrading existing machinery to facilitate integration, adjusting organisational structures). Hence, it should be expected that a firm experiencing low liquidity and one that cannot obtain funds either by means of borrowing or venture capital may be among technological laggards. Costs from adoption may also be non-monetary; getting accustomed to new technologies and dealing with potential problems and operational and organisational incompatibilities have an impact on staff motivation and overall efficiency. According to Rogers (1983) the extent to which a firm can afford the adoption of an innovation is closely related to the growth of demand for the technology as a product. As time passes the technology becomes standardised, its financial cost falls and its adoption generally becomes a less difficult experience.

Another factor associated with the social context within which the firms operate is the state of the *labour market*. In particular, the availability of certain skills and the cost of training staff locally is an important consideration. An educated labour force can contribute to R&D breakthroughs in an organisation and be in a better position to

[40] Pharmaceutical corporations invest heavily on R&D for new products. They usually look into numerous alternatives. Only a small proportion of potential products translate into a marketable proposition. Nevertheless, the market gains to be had by the possibility of an innovation justify the high level of risk.

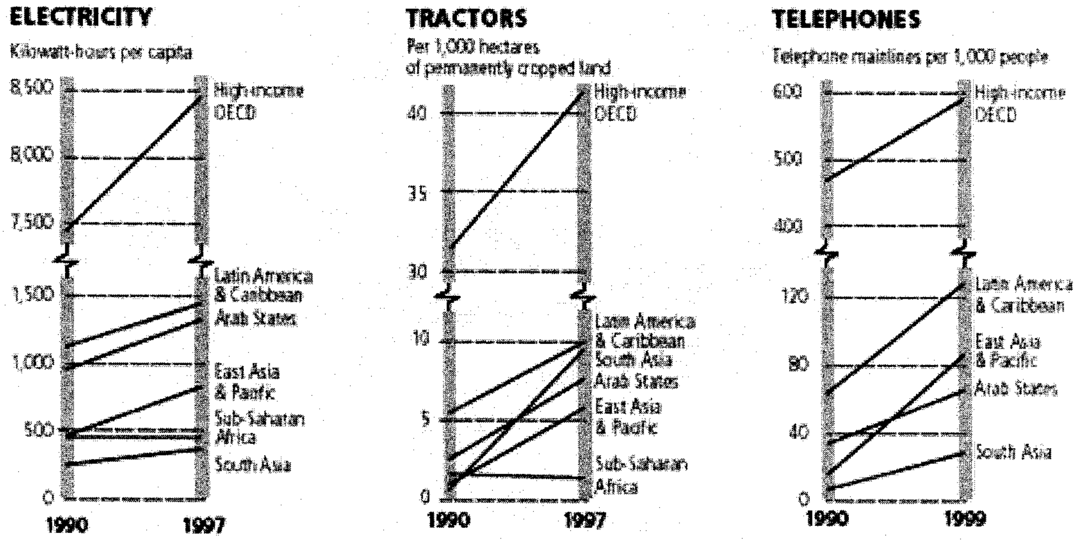
assimilate new technologies. The presence of vocational educational institutions and universities within the locality of the firms greatly enhances the ability of the workforce to cope with new technologies. Firms that use colleges and universities as training outlets for their workforce also benefit from networking effects.

Furthermore, what many theorists refer to as the *national culture* of the economy under question or the general *social attitudes* towards technical change is an important issue which reflects directly in the management of firms in a particular economy. According to Herbig and Dunphy (1998) the function of culture is to establish the rules of conduct, standards of performance, and ways of dealing with interpersonal and environmental relations that will reduce uncertainty, increase predictability, and thereby promote well-being and growth among the members of any society. Therefore, Herbig and Dunphy (1998) emphasise the role of culture as a determinant of social openness to new ideas. There are also those who argue that existing cultural conditions determine whether, when, how, and in what form a new innovation will be adopted (Foster, 1962). Cultures develop along 'evolutionary trajectories', with historical events having a strong influence on a culture's predispositions towards technology. If the behaviour, ideas, and material apparatus which must accompany the use of innovation can affect improvements along lines already laid down in the culture, the possibilities of acceptance are much greater (Saxon, 1954; Inglehart, 2001). Nevertheless, difficulties in defining culture and assessing the influence of its manifestations mean that it is a concept seldomly mentioned in diffusion studies.

3.3.2 Country Specific Factors

Environmental conditions that are specific to national boundaries have also been found to affect the diffusion process. As the varying diffusion experiences of technologies across countries indicate (Figure 3.2) the economic, political, social and cultural environment can often have an effect on the level of diffusion. This is evident in the vastly different international diffusion experiences of electricity, tractors and telephones. The magnitude of the diffusion gap is great in both absolute and relative terms. Higher income OECD countries adopted these technologies considerably faster than countries in Sub-Saharan Africa, East Asia, the Arab States or Latin America. It is interesting that East Asian countries are rapidly closing the gap for all technologies concerned. What is striking about this technological gap is the extent to which it is reminiscent of the group of countries' relative economic prosperity. This could be seen as implying a link between the capacity of an economy to absorb innovations and the developmental stage it finds it self in; a possible indication that Vernon's (1966) product cycle theory is also relevant to diffusion.

Figure 3.2
The international diffusion of electricity (1990-1997), tractors (1990-1997) and telephones (1990-1999)



Source: UN (2001), *Human Development Report: Making New Technologies Work for Human Development*: 41

There is broad acceptance that the diffusion of technology hinges on economic conditions – particularly when (as in the majority of cases) the technology involves a considerable adoption cost. Dicken (1998) argues that country-wide technological development is closely linked to economic development; the developmental stage an economy finds itself in, in terms of its sectoral structure is highly suggestive of its capacity to generate and assimilate innovations. Hence it would be logical to argue that an economy with a disproportionately large primary sector is less likely to be conducive to the adoption of new ideas than an industrial, and even more so a post-industrial economy. An agrarian, less developed economy usually supports a socio-political establishment that is also adverse to any form of novelty and change, technological or otherwise.

At the same time, economic development, in its modern sense, literally depends on technology; as Solow's (1956) research highlighted, technology can lead to significant marginal productivity improvements. Ironically developing countries are most in need of technology for sustainable economic growth and are simultaneously in the worst position to get it.

In addition, (as mentioned in Chapter 2) international trade is as important for technology transfer as it is for economic development. Ethier and Markusen (1991) point out that technology transfer is very often more than just a consequence of FDI flows. Indeed, technological opportunism has elevated technology transfer for many MNEs into a strategic objective. Therefore, the intensity of trade inflows as well as outflows could act as an indicator for the existence of diffusion channels.

Technology adoption studies at the microeconomic level (Cobham, 1999; Caselli and Coleman, 2001) have highlighted the economy-wide availability of financial capital, regardless of source, as a major determinant of diffusion. Financial stability required for technological investment can only be realised in a climate of macroeconomic stability. For that reason macroeconomic stability in the form of low inflation, accompanying low interest rates and a stable or at least predictable exchange rate are paramount in the diffusion process. An adverse macroeconomic outlook (for instance, high inflation, high interest rates and investor uncertainty) seriously affects the availability of finance and has an impact on the adoption of new technologies even when their profitability has been established. Caselli and Coleman (2001) also identify mixed economies as being better able to manage the assimilation of innovations than those with disproportionately large public sectors. The former are more likely to be present in a climate of political and social stability; pluralist, consensus politics and democratic participation usually accompany and support sustainable economic development. Moreover, trade barriers could cause the technology's cost to rise at levels that are prohibitive for diffusion. Membership of a regional trading block of countries with an established R&D tradition (such as the European Union, the NAFTA or the ASEAN) should in principle help towards reducing such costs. Membership of the European Union in particular can help in more than market-related technology transactions as various efforts for a co-ordinated innovation policy have materialised over the years. Therefore, on one hand political stability is important for sustaining strong economic fundamentals at home, while on the other hand good international relations can offer the opportunity of participation in international and supranational innovation systems.

There are also geographic and spatial considerations. Geographic proximity to economies with considerable innovative activity is considered a positive asset, paving the way for technology transfer in the form of spillovers. To contrast with, relative geographic isolation (e.g. in the cases of island states) could have the opposite effect. Indirect evidence to support such a case comes from the work of Abreu et al. (2004) measuring Total Factor Productivity (TFP) growth for 73 countries for the period 1963-2000. Abreu et al. (2004) found that TFP is highly associated with particular geographic localities and that high or low values tend to be clustered. The spatial balance between urban and rural areas could also affect the readiness of an economy to adopt new technologies. Since at its early stages the diffusion process hinges on communication, one could assume that it would not be encouraged by the spatial fragmentation of people and firms prevalent in rural areas. Furman, Porter and Stern (2002) provide evidence suggesting that the presence of regional industrial clusters can have a positive effect on the adoption of technology and the promotion of further innovation. There is evidence though to support that where non-diffusion in rural areas is widespread it comes down to the type (industry) of firms and their size rather than their location. In his study commissioned on behalf of the United States Department of Agriculture, Gale (1997) found only minimal differences on the type of technologies being used among urban and rural firms of comparable size and which operate in the same industry. Therefore the relative absence of advanced technology in rural areas may come down to the fact that the types of businesses (farms, fisheries, low-skilled services) that are common there have little use for innovations.

Institutional actors within an economy are also of great importance for diffusion. Publicly funded institutions such as universities and R&D institutes can encourage diffusion through linkages with firms (market transactions) as well as through human resource training and spillovers. An educational system which is in tune with the needs of the industry can also go some way to encouraging diffusion. Effective vocational training in emerging technologies in combination with industrial placements (Mehlinger, 1995) are measures that should enhance the prospects of diffusion.

As it is ultimately people that have to make effective use of technology, the characteristics of the local labour force is perhaps one of the most important determinants of intra-firm diffusion. Nelson and Phelps (1966) found evidence supporting a link between education, the creation of new ideas and ultimately productivity and economic growth.

3.4 Diffusion Theory in Economics

Even though economists have only recently researched systematically the mechanisms of technological diffusion and the factors affecting its success in spreading and the speed at which it does so, the study of the implications of diffusion can be traced back to the beginning of the 20th century. Marshall (1920) was probably the first economist to study the phenomenon of diffusion from an evolutionary perspective that was well ahead of his time. Diffusion models bear a methodological similarity with some of the models of industrial and economic growth developed in the 1930s by Kuznets (1941) and Schumpeter (1934, 1942)[41]. Schumpeter (1934) recognised the significance of technical change in stimulating the trade cycle (the long term Kondratieff cycle). He does not however analyse the forces driving diffusion nor its inner workings.

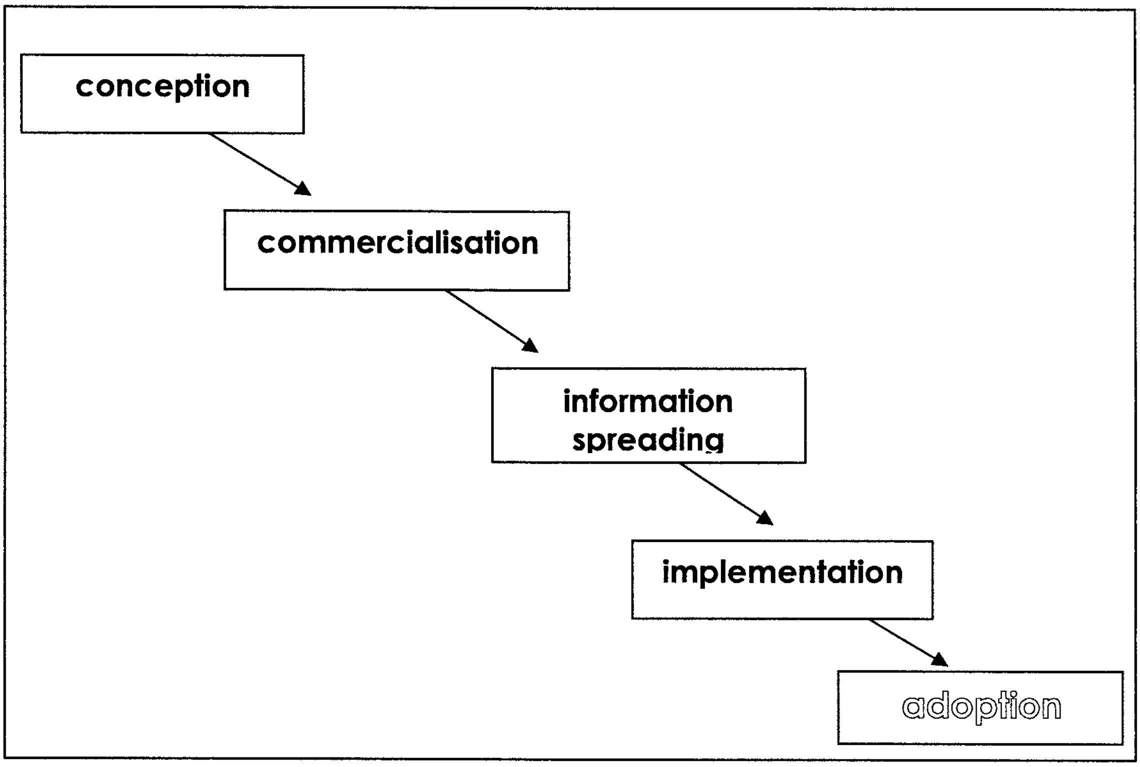
Diffusion is the process by which a product or process innovation spreads throughout the economy, resulting into events of economic significance. It is clear from the author's elaboration so far that due to reasons as simple as the sheer size of an

[41] The statistical work of Simon Kuznets, coupled with the theoretical advances of Joseph Schumpeter gave birth to the concepts of the business cycle and the field of development economics.

industry (or a national economy), the nature or price of the technology itself and the heterogeneity of the potential adopters, innovations do not diffuse instantly. Diffusion is a time consuming process (Figure 3.1). For example, it took almost twenty years from the initial advent of computer microprocessors until the first viable products (microcomputers) hit the market. It took almost a decade for microcomputers to reach any noticeable market penetration level and another decade for firms to implement the relevant technology in a way that generates profit (Stoneman, 1976).

More than anything else, the study of diffusion in economics is concerned with assessing the changing economic importance of a technology over time. Figure 3.3 illustrates the distinct stages a technology passes on its way to adoption. Progression from each stage to another usually involves overcoming abundant barriers. When a technology is first conceived, it takes a great deal of investment for the originator to refine it and transform it into a commercially viable product. This often goes beyond traditional R&D and involves gauging market demand and adjusting the technology accordingly. In turn, information spreading has to occur, which is in many ways related to the profitability of the innovation and its observability. The technology supplier can affect its observability in this stage by direct marketing and advertising. Depending on the competition regime the technology's supplier is facing one can argue that information spreading may occur more slowly in industries with a high concentration of innovators. As many competing technologies challenge the potential adopters' attention, information spreading is slow and even when it does occur the decision to adopt becomes a difficult one. Contrarily, if the competition regime for technologies of this kind resembles closely a monopoly then chances are that information spreading may be almost instantaneous, as potential adopters narrow down their technological scanning to a single supplier[42]. As is natural, for a technology to reach the adoption stage for a large share of its potential adopters, its positive merits must have been established. Even when information spreading occurs, and potential adopters are willing to adopt, obstacles such as copyrights and patents[43] and the availability of finance may stand in their way. Finally a certain amount of potential adopters will never implement the technology because of compatibility issues, complexity issues and the fact that they were unable to finance its implementation.

Figure 3.3 – The Diffusion Process



[42] Arguably, this is the case with Microsoft's Windows Operating System for PCs. Due to its near monopoly position and the importance of the software for many firms, even an incremental technological improvement usually receives sufficient press coverage to result in widespread familiarisation of potential adopters with the technology.
[43] For an analysis of the impact of copyrights and patents in technology markets see McDonald (1983), Grossman (2000), Rogers (1983) and OECD (1997).

Inappropriateness (Geroski, 1995) of a technology or general uncertainty is a major issue. Uncertainty is created when the perceived relative advantage of a technology is low or technical change is so rapid in a particular industry that the technology is in danger of completing its life cycle before generating sufficient profits to cover the investment in adopting it. A good example of such a case is the currently troubled technology of third-generation (3G) mobile telephony[44].

Even when the merits of a new technology are not doubted, a number of factors such as cost, complexity and internal factors prohibit its quick diffusion. For instance, the purchase and implementation of the technology may be very expensive, as the innovator is trying to recover the costs incurred during research and development. At the same time, the innovator is enjoying imperfect competition in a monopoly state market. In certain instances copyrights and patents may extend this monopolisation of technology and further retard the diffusion process. Opportunities for further profits through product differentiation, cost cutting and productivity gains present a huge incentive in favour of adoption. Imitation eventually takes place overcoming legal barriers, and mass production and economies of scale push the cost down to

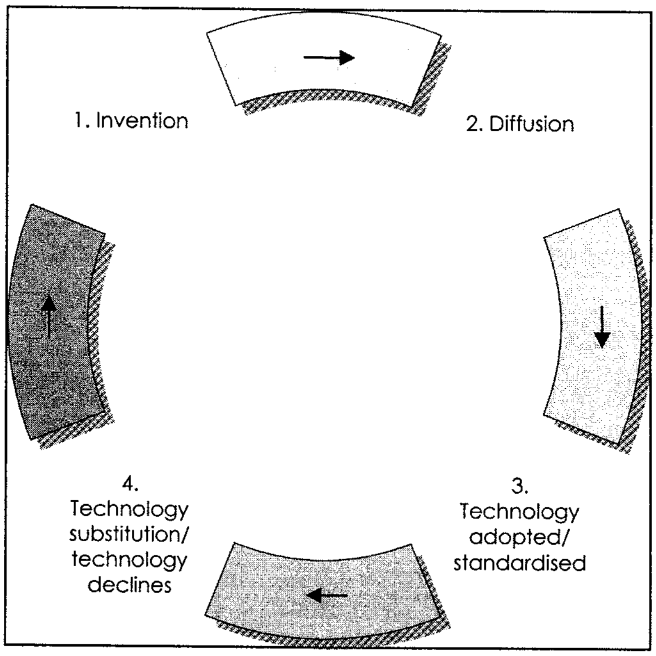
[44] Third generation mobile telephony networks were initially expected to be operational by the end of 2002. Collectively referred to as 3G, it is a set of technologies to be embedded into future mobile communication devices promising to deliver multimedia-rich services such as videoconferencing, audio/video streaming, high speed data transfer etc. 3G operates at different wireless frequency spectrums than conventional mobile telephony (GSM) and as a result requires new operating licenses to be granted by governments. The high anticipated profits for the services 3G has promised generated huge demand on the part of network operators (and thus exceedingly high prices) for the limited number of broadcast licenses. As a result of bidding for these licenses in late 2000, a number of mobile phone operators were brought on the brink of bankruptcy (BT Cellnet, now known as O2, is such an example). The future of 3G telephony is still uncertain, as a number of cheaper technological alternatives have since been developed (i.e. 802.11b wireless networks a.k.a. 'WiFi' and 4G), mobile operators push back its launch date due to numerous hardware glitches and device manufacturers persistently refuse to design and produce 3G-compatible handsets that would attract customer attention.

encourage widespread use of the innovation. Diffusion is important as the process itself in the end deteriorates the competitive edge of the innovator and yields benefits for the economy as a whole.

To appreciate the importance of diffusion in economics one needs to afford a look at the life cycle of a technology (Figure 3.4) from invention to its eventual substitution. After the invention of a technology, diffusion takes place; it is the most critical part of its life cycle as it determines to what extent the economy will benefit from its qualities. For instance, Ford's manufacturing assembly line is a process technology; the success of its diffusion during the early 20th century greatly enhanced productivity in the automobile industry and its application into a number of industries has been argued to have increased the pace of economic growth[45]. The life cycle of a technique is eventually completed when a new technology is invented and it gradually substitutes the old one (Figure 3.4).

[45] Castells (1996) goes as far as arguing that Ford's assembly line established a new 'techno-economic' paradigm, thus fundamentally altering the nature of economic relationships throughout the 20th century.

Figure 3.4 – The Life Cycle of a Technology



The reasons why firms do not instantaneously adopt new technology immediately after its commercialisation are the subject of the study of diffusion. A great deal of research has been devoted in identifying the factors that can inhibit the process or make it faster. A variety of different models (epidemics, equilibrium, probit/logit and game-theory) have been employed in the search for diffusion catalysts, producing a mixture of insights. Nevertheless as a whole, they have created a comprehensive framework upon which the present study of diffusion can be based.

3.4.1 Epidemic Models

In the early 1950s, literature on the subject of technological diffusion was pioneered and then dominated by what came to be known as 'epidemic theories'. Griliches

(1957) conducted empirical research in the spread of hybrid corn among American farmers on the grounds that technological diffusion follows similar patterns to the spread of a disease among a given population. Korres (1998) explains that the basic epidemic model was then based on three assumptions;

(i) The potential number of adopters may not be in each case the whole population under view.
(ii) The way in which information spreads may not be uniform and homogenous.
(iii)The probability to optimise the innovation once informed is not dependent on economic considerations, such as profitability and market perspectives.

With his works in 1961, 1963 and 1964 Mansfield took the theory of epidemics further. He used empirical evidence from several different industries in the United States and investigated the diffusion path of certain technologies in each industry. He found that different firms in the same industry had varied attitudes towards the adoption of new technology; some embraced technical advances as soon as they became available, whereas others were much more reluctant. Mansfield devised a simple deterministic model that measures the diffusion rate of a technology in relation to factors such as the profitability of installing this technology, the investment cost involved, the life expectancy[46] of the technology, and the rate at which the firms are expanding. This model is useful in determining how the innovation spreads from one firm to others, the speed by which it does so and which factors may retard this process or even prohibit it. Mansfield's assumption was that

[46] Mansfield allowed for a Shumpeter-inspired discount rate for technological investment over time.

the resulting inter-firm diffusion curve would be sigmoid (S-shaped) and would be characterised by a logistic curve (epidemic model) as the key explanatory variable in his model was the spreading of information.

When the innovation becomes initially available little is known about it and only a few firms adopt. As the first few adopters start using it the positive yield from its use becomes increasingly apparent. In time, the number of adopters increases, in turn causing greater numbers of potential adopters to come in contact with the technology; diffusion of information occurs and the rate of adoption accelerates. Hence the technology spreads like a virus does in an epidemic with the rate of adoption frequently referred to as 'contagion rate' or 'infection rate'. Mansfield assumed that towards the end of the technology's lifecycle, the rate of adoption decreases as firms turn to the innovation's successor. That was a proposition which was largely verified by the results of his empirical work.

A number of more modern diffusion models (Davies, 1979; Stoneman, 1983) are also based on the theory of epidemics. Given the importance of epidemics in shaping diffusion theory up to the present day, it would be advantageous to illustrate the workings of such models in simple mathematical notation. The theory of epidemics broadly assumes that the diffusion of a new technology among a fixed number of identical firms takes place as follows. The level of diffusion D corresponds to an m_t number of firms in a fixed population of n which have adopted the new technology at time t.

$$D = m_t / n \qquad (3.1)$$

At the same time (n- m_t) firms are the remaining potential adopters. One may define β as the probability of adoption (Korres, 1998), also known as the rate of infection (Stoneman, 1983), or the speed of diffusion (Mansfield, 1968) which in the present case is assumed to be constant. Under an epidemic model it is also assumed that non-adopters become adopters upon receipt of information on the existence of new technology. If one assumes that n is a homogenous population, then for a very small period of time Δt (from t to Dt), the probability for a susceptible firm to meet a user and obtain information is $\beta(m_t/n)$. The number of non-adopters susceptible to adoption upon contact is $n- m_t$. Then

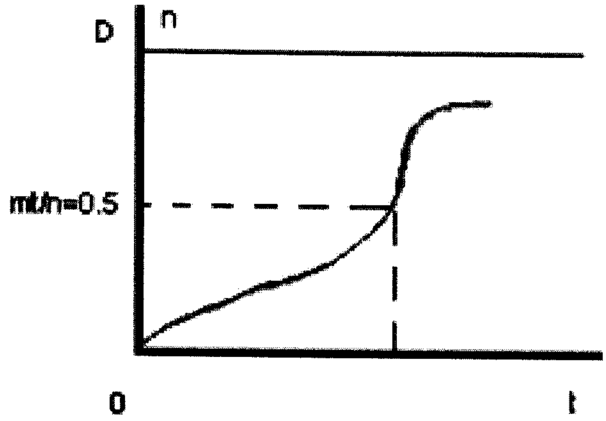
$$\Delta m_t = \beta\, (m_t/n)\, (n- m_t)\, \Delta t \qquad (3.2)$$

When the above (3.2) differential equation is solved, it shows that

$$m_t / n = 1 / 1{+}exp{-}(\alpha{+}\beta t) \qquad (3.3)$$

Where α is a constant of integration. Stoneman (1983), Davies (1979), Korres (1997) and Gourlay (1998, 2000) all conclude to the same logistic function solution. Therefore, by plotting the level of diffusion D against time we produce the logistic epidemic curve (Figure 3.5).

Figure 3.5 - The Logistic Epidemic Curve



Source: Korres, 1997

The path such a curve follows is sigmoid, as is typical of the diffusion process. The curve in Figure 3.4 indicates that the proportion of the population which has been in contact with the disease will rise at an accelerating rate until the innovation has spread to half the potential adopters. From this point on, the infection continues at a steady rate until it eventually decelerates.

However, this simple form of the epidemic model has various shortcomings. Specifically, it ignores effects of the technology's cost and its expected profitability. Mansfield expanded the basic epidemic model to cater for the effects of uncertainty on firms' decision to adopt. He believed that the importance of information spreading about simply its existence came second to uncertainty surrounding new technology as a result of poor information on its performance characteristics. Mansfield introduced the cumulative learning concept (learning through experience) which reduces uncertainty over time. Under this assumption and using m_t and n like before, Mansfield (1968) defined D_t as:

$$D_t = (m_{t+1} - m_t) / (n - m_t) \qquad (3.4)$$

D_t equals the proportion of non-users who become users in the interval t to $t+1$. Mansfield (cited in Karshenas and Stoneman, 1995) then carries on suggesting that:

$$D_t = G\ \{U_t, \pi, K, \ldots\} \text{ where } G_1 < 0, G_2 > 0, G_3 < 0 \qquad (3.5)$$

He represents U_t as the uncertainty attached to the adoption of the technology in time t, π as the profitability of installing the innovation (which is considered not to change over time) and K as the cost of adoption. Mansfield argues that uncertainty (U_t) diminishes as more and more firms implement the innovation (i.e. m_t/n increases). Consequently:

$$D_t = F\ \{ m_t/n, \pi, K, \ldots\} \qquad (3.6)$$

Mansfield then incorporates β in the equation as a linear combination of π and K:

$$\beta = b_1 + b_2\pi + b_3K + \epsilon \qquad (3.7)$$

In 3.7 the speed of diffusion (β) is a positive function of profitability and a negative function of the size of investment required.

Karshenas and Stoneman (1995), Korres (1997) and Geroski (1999) agree that epidemics models may be useful in helping researchers get a basic understanding of the diffusion mechanisms but many of their assumptions are flawed and their practical applicability minimal. More specifically they are constrained by:

(i) The assumption of linearity; they ignore the fact that the effect of the appeal of a technology and its characteristics (β, i.e. its 'infectiousness') changes over time. As more and more firms adopt an innovation the positive yields from its use rise. This is due to the fact that the technology is likely to be improved upon over time and also due to network effects (owed to compatibility, observability).

(ii) The fact that the population of firms in any particular industry almost never remains constant. By stressing the importance of the remaining stock of non-adopters, epidemics models ignore the dynamic nature of industries.

(iii) They are particularly unrealistic in assuming that information spreading equals diffusion; they fail to take into account the complexity of the decision making process.

On top of all these disadvantages of epidemics models, Karshenas and Stoneman (1995) point out that they are further limited by looking only on the demand side. They cite the work of Glaister (1972, cited in Karshenas and Stoneman, 1995), who was the first to recognise that for practical reasons supply side factors should be taken into consideration.

Table 3.2 – Epidemic Models: Demand Versus Supply Side Factors

Demand Side Factors (Potential Adopters)	Supply Side Factors (Technology Suppliers)
Profitability (perceived)	Cost of acquiring
Cost of search for technology	Cost of advertising (i.e. increasing observability)
Size of the firm	
Availability of finance	

Glaister introduced the factors of the cost of acquiring the technology and the cost of advertising (what would be later referred to as increasing 'observability'). Karshenas and Stoneman (1995) also point to the contributions of Metcalfe (1981) and Tonks (1986) built upon the work of Glaister, producing epidemic models with supply side considerations. Even though such models advanced our understanding of diffusion the main criticism still remains; they are unrealistically simple. Indeed, Karshenas and Stoneman (1995) describe them as 'primitive' and Gourlay (1998) suggests they are a good starting point, but not much more than that.

3.4.2 Rational Choice Theories

One of the major disadvantages of the epidemics approach to diffusion has been its assumption that adopters are passive recipients of information and that innovators always actively seek to spread information about it. In reality decisions on technological investment represent an individual rational choice between adoption and non-adoption. Hence, the occurrence of diffusion (a macroeconomic event) is analysed from a microeconomic perspective (the individual potential adopter's decision). Rational choice theories assume that firms behave optimally, (i.e. are profit maximisers) and that information pertaining to the technological and economic characteristics of the innovation is perfect.

In contrast with epidemic models, rational choice models are equilibrium models in that they assume that there is perfect information in the economy on the existence and nature of new technologies. Such models were initially developed to cater to the inefficiencies caused by epidemic disequilibrium models[47] but gradually evolved into a methodologically distinct approach. As Karshenas and Stoneman (1995) point out equilibrium models tend, for demonstratory purposes, to ignore the effects of intra-firm diffusion, assuming that firms only buy a single unit of the technology under question[48]. Rank, stock and order effects models along with probit, logit and game theoretic models belong to this category. One could argue that in the contemporary interconnected world information about technologies is indeed perfect (or at least close enough) and that the decision of when to adopt is dependent on other factors, often conscious ones.

[47] As Karshenas and Stoneman (1995) point out, information-based models are essentially disequilibrium models as they conceive an end level of diffusion and the diffusion path is determined by the end point (m_t/n).

[48] Technology adoption is a microeconomic event occurring in discrete time, whereas diffusion (an aggregate of adoption decisions) is a macroeconomic event, occurring in continuous time. Since equilibrium models are concerned with the microeconomic determinants of adoption it is perhaps innocuous to treat diffusion as a dichotomous event (adoption/non-adoption).

(i) Rank (Probit and Logit) Models

The rank or probit/logit theories on technological diffusion assume that different firms adopt a technology at different times because of their inherent characteristics. Potential users of a new technology differ from each other in some important dimension such that some firms obtain a greater gross return from new technology than do others. Davies (1979) ranked firms in terms of the positive yield they would obtain from the adoption of a new technology. Such an approach is extremely useful as apart from the rate of diffusion it can give us an indication as to which firms will be early adopters and which will be late.

Probit models use a cumulative probability function (CPF) in order to explain a dichotomous dependent variable. The range of the cumulative probability function lies between 0 and 1 and essentially assumes a normal distribution. The resulting probability distribution is often presented as:

$$P_i = F(a+bX_i) = F(Z_i) \qquad (3.8)$$

Where P_i is the probability of adoption for a firm i and X_i the independent variable, in this case the size of the firm. In the present case, the size of the firm is used as a proxy of its ability to adopt the technology; the normal distribution of probabilities also implies that the decision to adopt is analysed from a static viewpoint. The model is often transformed using a cumulative distribution function (Davies, 1979; Korres, 1997; Geroski, 1999); plotting $F(Z_i)$ over time produces the familiar S-shaped curve, as seen previously in figure 3.1.

The logit model could be seen as a version of the probit model based on logistic distribution. Its main advantage over the probit model lies with the fact that it can yield useful comparative estimates of the effects of different independent variables by producing estimated odds (i.e. the probability that a single unit increase in one independent variable will cause an expected outcome in the dependent variable, all other variables constant). A recent example of an empirical study employing a logit model is the work of Bartoloni and Baussola (2001). Bartoloni and Baussola (2001) modelled the adoption decisions of Italian manufacturing firms and found strong evidence for the importance of firm characteristics (ranked firm size) as well as industrial sector specificities.

The main criticism of both approaches is that they perceive adopters as passive actors whose decision to adopt is determined solely by their characteristics. Gourlay (1998) criticises probit models because they ignore strategic behaviour on the part of the potential adopters. In addition, probit and logit models take a static view of diffusion ignoring the effects of time on diffusion determinants. Still, it is precisely this static approach that is particularly advantageous at modelling decision-making when information spreading has already occurred.

(ii) *Game-Theoretic Models*

The application of game theory to the diffusion of technologies is similar to ranked probit and logit models in that its focus of attention is the individual decision maker (the decision to adopt). The theoretical contributions of Reinganum (1981 and 1983) are good examples of the portrayal of diffusion as an oligopoly game. Just as in the probit and logit models there exists an assumption of perfect information. However unlike probit and logit models the individual firms characteristics are not supposed to account for their adoption behaviour; the stress is rather on situational factors (e.g. competition) and the adopters' acting strategically upon them.

Therefore, Reinganum's model assumes that identical firms attempt to maximise their utility from the adoption of an innovation while minimising the costs of doing so. Reinganum (1981) found that the timing of adoption among otherwise identical adopters is conditioned by the firm's weighing of the expected benefits versus the expected costs. While the cost of adoption decreases over time, the profitability of a technology also decreases as the number of adopters grows. The relative rate of such decreases changes as the number of adopters increases and ultimately determines adoption decisions. She derived a Nash equilibrium showing that firms adopt at different points in time as they act strategically based on the behaviour of the competition. This is despite the firms involved being identical. Reinganum's model was expanded by Huisman and Kort (2000) to include technological uncertainty and more specifically, to model their expectations regarding future technological improvements.

Kemp (1997) criticises game theoretic models in that they are unable to reproduce the experiential sigmoid diffusion pattern. Karshenas and Stoneman (1995) also find that the static viewpoint of game theoretical approaches is unrealistic. Strategic considerations probably do influence individual adoption decisions and ultimately have an effect on overall diffusion but experience tells us that firm characteristics and information spreading are also important.

(iii) Evolutionary Models

Evolutionary theories in economics were developed as attempts to explain changing economic structures over time. Such theories (Marshall, 1920, Witt 1991) tend to draw analogies between innovation and diffusion and natural selection; in evolutionary terms, technology is to human knowledge what genes are to life. It is indeed true that at the theoretical level there exists a curious resemblance between the diffusion of new technology (the evolution of human knowledge) and the spreading and prevalence of new genes through the process of natural selection. In such an analogy innovation (the creation of knowledge) can be likened to gene mutation (the formation of a distinct gene). In biology, evolutionary theory proposes that new (mutated) genes do survive and become commonplace among a species because they are more successful (in assisting the organism to survive and procreate) than competing genes. In the same fashion, evolutionary economic theories propose that technologies which are more successful in securing profits for firms tend to be universally adopted and in a sort time period through a process of artificial, rather than natural selection. An obvious question that arises is; *to what extent can biological models aimed at predicting the speed at which mutated genes become spread can be applied in the field of economics?*

Unlike, game theoretical models, evolutionary diffusion models assume that potential adopters are not identical (Nelson and Winter, 1982). Just like probit and logit models they assume that differing characteristics account for the variable adoption dates among a given population. It is important to note that evolutionary models are disequilibrium models; time is a very important factor in such models and the influence of any determinants is dynamic. There is also a selection mechanism based on the technology's relative advantage (e.g. its profitability). This perceived relative advantage is influenced over time by the total level of diffusion in such a way as to decrease while the stock of adopters increases (Geroski, 1995).

While the model has strong merits in that it explicitly allows for a discount in the technological utility over time it is limited in its scope in that it assigns a deterministic role solely to expected benefits. Importantly, evolutionary models shift the focus of attention to the population as whole. They demonstrate the significance of the population in the individual's adoption decision.

Perhaps a major weakness of evolutionary approaches is their inability to deal with non-gradual patterns of technological progress, the so-called technological leaps. Loch and Huberman (1999) catered for such a deficiency by developing an evolutionary model allowing for radical changes over smaller time periods. An obvious danger in such an approach is that one can rely too much on biological analogies; economic systems are by no means totally dependent on positive yields. The rational decision making process is much more complex and is influenced by both internal and external factors (see §3.2 and §3.3). Furthermore, the evolutionary models' overall complexity makes its application to empirical datasets difficult and often restricts it to the theoretical arena.

3.5 Towards A Unified Approach

The evolution of economic theory on the subject of technological diffusion initially produced two distinct schools of thought. Though distinct, they have not been conflicting and their relationship can be best described as one of complementarity and continuity. On one hand, theorists like Griliches (1957) and Mansfield (1961, 1962) investigated technological diffusion according to epidemics and the spread of information. The focus of these theorists had been the research of the speed by which information spreads, and the identification of factors which affect information diffusion. In other words, they believed that diffusion of information is synonymous to diffusion of adoption (see §1.1), assuming that decision making is solely based on the availability of information. Ironic as it may be, rapid advances in information and telecommunication technologies since the formation of these theories, have rendered the importance of information spreading as a factor for the speed of adoption, less relevant, though still important.

On the other hand, first Mansfield (1964) and then Dosi and Soete (1974), Reinganum (1981), Nelson and Winter (1982), Metcalfe (1984), Stoneman (1995) and others see economic agents as rational actors which make a decision on the adoption of technology based on its perceived benefits and costs. Such models did not altogether dismiss earlier epidemic theories on diffusion, but rather built upon them, utilising different assumptions and ultimately developing totally different perspectives. On these premises, as we have already seen a number of models were developed (epidemic, probit/logit, game theoretic and evolutionary) which significantly advanced economic theory on the subject, whilst each had its individual shortcomings. The logit model adopted in this project, borrows ideas from many different approaches and attempts to unify them. At the same time, it is constrained by many of the original limitations that each approach has. Nevertheless, as Gourlay (1998) and Stoneman (1995) have shown, it can yield useful insights into the workings of diffusion and is an approach that promises a lot in the new 'information economy'.

In the modern world, as information on the advent of innovations spreads very quickly one could argue that the diffusion of information occurs much faster and in this context it is less relevant. This raises the possibility of individual adoption decisions influencing the lag – the question is which factors affect the decision to adopt and how their weight differs according to firm size, behaviour, industry characteristics and the overall economic environment.

3.6 Conclusion

The present chapter compared and contrasted the main theoretical contributions on the phenomenon of diffusion. The most important determinants of the spread of a technology across a set of potential adopters were looked at. In turn, the author presented past attempts to model the overall diffusion of an innovation and individual adoption decisions with a potential for empirical application. While economic measures and agents play a central role in the diffusion process, our present understanding encompasses broader social determinants.

Finally, the author elaborated on the possibility of unifying methodologically distinct approaches into one that is informed by the contributions of all. Indeed, technologies are so diverse in nature and so unpredictable in their long term evolution that an all encompassing theory may never come into being. Despite this, our existing understanding of the process allows us to break down the problem into its component parts, narrow down our research questions and search for specific determinants, within specific environments for pre-determined time periods.

Chapter 4 - Greece and Technology

I woke up with this marble head in my hands;
it exhausts my elbows and I don't know where to put it down.
George Seferis, "Mythistorima", pt. 3.1

4.1 Country outline; Past and Current Economic Outlook

4.1.1 A Brief Economic History of Modern Greece

Even though Greece's existence as an independent political entity can be traced back to the early 19th century, a legacy of political instability, conflict and foreign intervention prevented any noteworthy events of economic significance in the first half of its history. Alogoskoufis (1997) and Drakatos (1997) agree that it was not until the end of the 19th century that any significant economic development took place in Greece[49]. Even this beginning was problematic, interrupted by the Balkan wars, the Great Depression, the two World Wars and a devastating civil war that was to haunt Greek political life for decades. At the beginning of the 20th century the Greek economy was overwhelmingly agrarian, with only sporadic attempts towards the creation of a secondary and tertiary sector. Industry at the turn of the century consisted primarily of food processing, shipbuilding, the manufacture of textiles and simple consumer products. The first half of the twentieth century saw limited development fuelled mainly by capital from Greek entrepreneurs of international stature. This period was also characterised by protectionist measures and heavy government involvement in economic affairs (Drakatos, 1997).

[49] Greece defaulted in 1893 as a result of (among other things) the problematic consolidation of state authority, a series of wars, wide-spread corruption and excessive borrowing. The Greek Prime Minister at the time *Charilaos Trikoupis* admitted responsibility in a declaration before parliament that still resonates in modern Greek politics as a stark reminder; "*Gentlemen, unfortunately, we are bankrupt!*" This event served to concentrate national efforts on economic affairs and displaced territorial expansionism as the primary policy priority, in favour of economic development.

The German occupation[50] (1941-1944) and the consequent civil war (1943-1949) had far reaching consequences; the industrial capacity of the country had been annihilated, most services were disrupted, there was extensive capital flight and high unemployment. The capital flight of the pre-war years was followed by a large-scale emigration trend, resulting in a loss of human capital[51]. The Greek economy began growing rapidly only in the beginning of the 1960s when capital inflows from loans and Greeks working abroad revitalised the economy and provided the basis for the development of significant textile, construction and shipping industries.

Greece's legislative complexity, socialist tradition, disproportionate in relation to its ability welfare provisions, militant trade unions, political instability (with its most recent manifestation in 1967, when a military junta displaced democratic institutions) and relatively high level of corruption incidences[52] have hampered growth (Figure 4.2). These characteristics combined with a globally adverse macroeconomic outlook for most of the 1970s, created long periods of monetary instability and high inflation (Figure 4.1 and 4.2).

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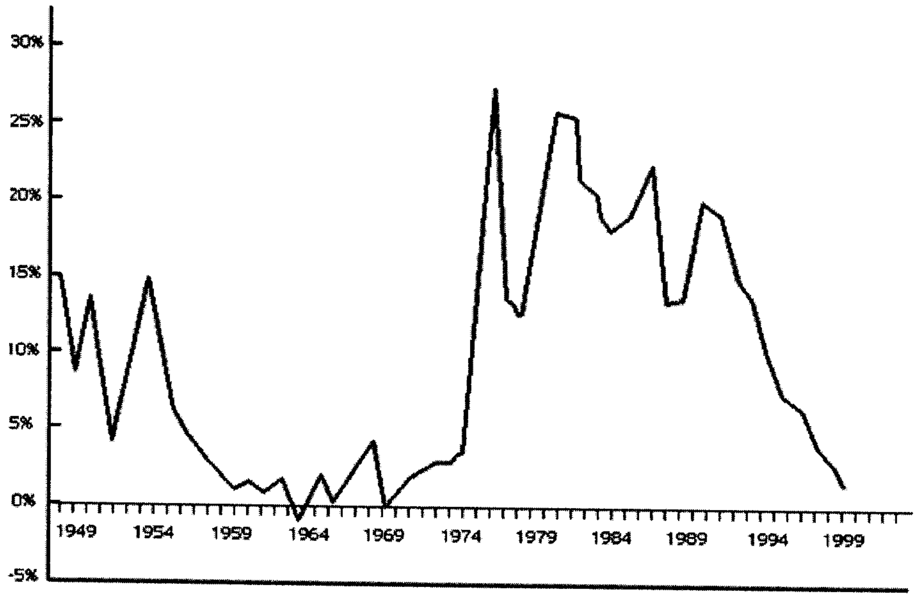
[50] For a detailed economic review of the period see Economic Post (1999) "*Landmarks of the Greek Economy in the 20th Century*".
[51] The immigration flow was particularly common among high-skilled Greek workers (Drakatos, 1997) resulting in a so-called 'brain-drain' that was to contribute to Greece's limited ability to generate industry-applicable R&D.
[52] Greece is ranked 44th in the Corruption Perception Index of Transparency International, with a CPI score of 4.2. CPI relates to perceptions of the degree of corruption as seen by business people, academics and risk analysts, and ranges between 10 (highly clean) and 0 (highly corrupt) (Transparency International, 2002).

Figure 4.1 - Greece: Average Annual Inflation Rate (CPI), 1949-1999



Source: Dertilis and Fragkiadis (1999: 70)

In 1974 the dictatorship collapsed and the country sought to re-establish itself as a modern western-style democracy. The institution of monarchy was abolished and a constitution was devised that undermined the old political antagonisms that led to the creation of the junta regime in the first place. The creation of a pluralist and liberal political system created a solid basis for economic recovery. Unfortunately, such a recovery did not materialise immediately as prices soared in the aftermath of the successive OPEC oil crises (1973 and 1979).

As Greece joined the EEC in 1981 the need for fiscal prudence came second to the need to modernise the country's antiquated public infrastructure. The socialist governments that took office in the 1980s engaged in an unprecedented round of public spending. Excess spending in combination with low taxes and the absence of measures to combat widespread tax fraud created a disproportionate public deficit and fuelled the rise of inflation, which was to remain close to 20 per cent for most of the decade. Very little of this spending was directed towards any kind of innovative activity or technological infrastructure. Notable exceptions were attempts to modernise the Greek primary sector (agriculture, fisheries, minerals) and funds directed at Greek Universities and Research Institutes. The modernisation of the primary sector materialised in the form of subsidising for the purchase of imported equipment. Its positive contribution was limited to a one-off effect in productivity gains and international competitiveness. Arguably, money directed towards universities encouraged the creation of a nascent research community and backed it with fledging infrastructure[53].

The effects of this period of spending on external borrowing were negative but not detrimental as a great proportion of the funds needed came from the EEC in the form of regional subsidies and the EEC Support Framework (Dertilis and Fragkiadis, 1999). However negative the immediate effects of the 1980s spending programme may have been to the country's national accounts, it can be argued that the creation of a welfare state (a national health system, a consolidated benefits framework and free education) along with a partial modernisation of physical infrastructure, established initial foundations for long-term economic stability. The EEC Common Agricultural

[53] FORTHnet, a national computer network facilitating data interchange among Greek Universities and Research Institutes and linking them with similar networks abroad was initiated in 1984. Its later commercialisation paved the way for the spread of the Internet in Greece. Today FORTHnet is one of the largest Internet Service Providers (ISPs) in Greece.

Policy also contributed greatly to financing modernisation and structural change in the Greek countryside[54].

Market liberalisation and the dismantling of the huge public sector only started in 1989 by the then conservative administration. Nevertheless it was limited in scope and it enjoyed mixed success. Privatisation of state industries was met with a strong backlash from trade unions in a set of consecutive strikes that brought the country to a standstill. It was also shadowed by a number of well-publicised scandals[55] that eventually led to early elections and the return of the socialists to power. A 'roller coaster' cycle of pre-election largesse and post-election stringency in public spending (i.e. a political trade cycle) has been apparent under both conservative and socialist governments in the 1980s and 1990s (The Library of Congress, 2003). The latest socialist governments have changed their attitude towards economic policymaking and in doing so moved themselves closer to the neo-liberal side of the ideological spectrum[56]. Concerted efforts have taken place from 1994 onwards to limit the size and influence of the public sector in the economy and the government has pressed ahead with privatisation although at a slower pace than some think is necessary (Economist, 2002). It was only in the second half of the 1990s, under heavy pressure

[54] Though arguably it did little to promote the long-term international competitiveness of the agricultural sector; while it financed one-off infrastructural projects it also contributed to the conservation of antiquated industrial structures.

[55] In the early 1990s (among other things) allegations that the government 'sold-off' public enterprises to 'vested interests' that sought to damage competition, raised corruption suspicions, undermined the government's approval ratings and led to early general elections. Some well-publicised cases include the privatisations of AGET-Hercules Cement, Softex S.A., Piraiki-Patraiki and ETHEL (what was then the Athens Transport Corporation).

[56] Such an ideological shift became typical of centre-left political parties in this period. One can draw parallels between the transformation that occurred in the Greek socialist party (known as PASOK, an acronym for the Greek terms for *Panhellenic Socialist Movement*) under the leadership of Konstantinos Simitis and the re-birth of the British Labour Party under the leadership of Tony Blair and the advent of 'New Labour'.

to meet the criteria to join the single European currency that seemingly effective policies against inflation were introduced.

The labour market in Greece is still considered to be one of the most rigid in Europe, with trade unions being a powerful actor in determining economic policy. At present, Greece's powerful trade unions are blamed for the slow pace of the country's market liberalisation process. At the same time, the contribution of trade unions in the democratisation of the political system is notable. At the end of the 1990s, Greece had consolidated the institutional framework needed for long-term growth[57] and the process of market-liberalisation was taking place in a gradual manner while seeking broader social consensus. The beginning of the twenty-first century brought great challenges to Greece (in the form of adopting to the Euro and hosting the 2004 Olympic Games in Athens) and as many analysts (EIU, 1998; Sanai, 1998; Economist, 2002) mention in some form or another, created a feeling of optimism for its long-term future.

4.1.2 Greek Economy – Indicators

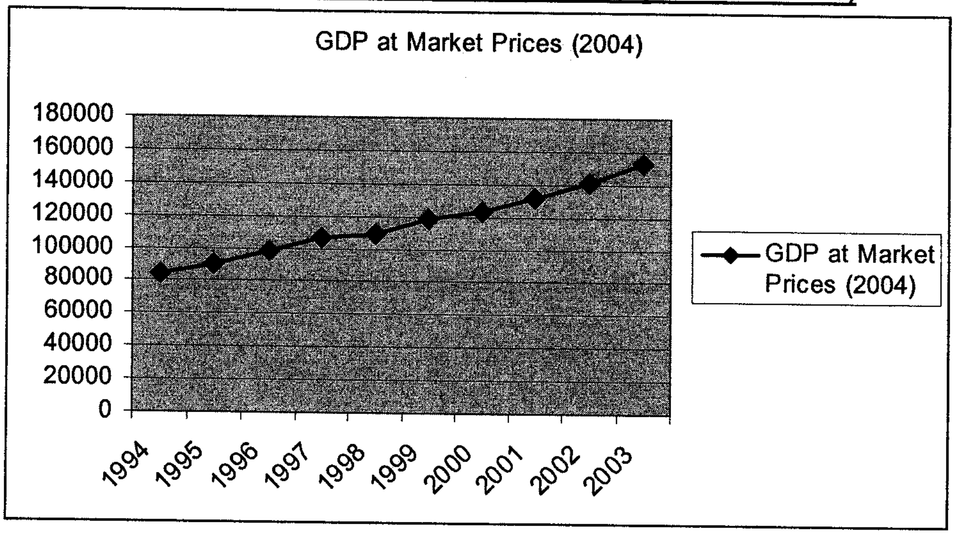
- *Macroeconomic indicators*

The Economist (2002) sees the current success of the Greek economy as *'both a cause and a reflection of its enhanced status in the European Union'*. This translates into high GDP growth rates which averaged 4 per cent in the period 1995-2000 and was still close to 4 per cent at the end of 2002 (see Figure 4.2, Table 4.1), rising household spending and a surprisingly low (by Greek standards) inflation rate at 3.5

[57] The education system, despite its qualitative shortcomings, is largely effective and has contributed to the creation of a skilled labour force. Despite a high perception of corruption among other public officials, the Greek Justice system is widely perceived to be effective and trustworthy. Government regulators at newly liberalised industries have also developed a reputation for being impartial.

per cent (National Statistics Service, 2003). The steady growth rates experienced throughout the 1990s are attributed chiefly to capital injections from the EU, the improved competitiveness of key industries following liberalisation and multinational capital inflows. Given the short period during which any considerable amount of economic growth has occurred, the role of technological inputs in achieving marginal productivity increases is still unclear at present.

Figure 4.2 – Greece: GDP, 1994-2003
Millions of euro (from 1/1/1999)/ECU (up to 31/12/1998)



Source: Eurostat (2004a)

Table 4.1 – Greece: Selected Macroeconomic Indicators

In million euros (2003 prices)	1993	1997	2000	2001	2002
GNP	62,028	97,235	121,628	130,927	141,132
Public debt	69,236	105,186	129,181	140,047	148,023
Debt as % of GDP	111.6	108.2	106.2	107	104.9
GDP Growth (%)	1	4.2	5.1	4.9	4.3

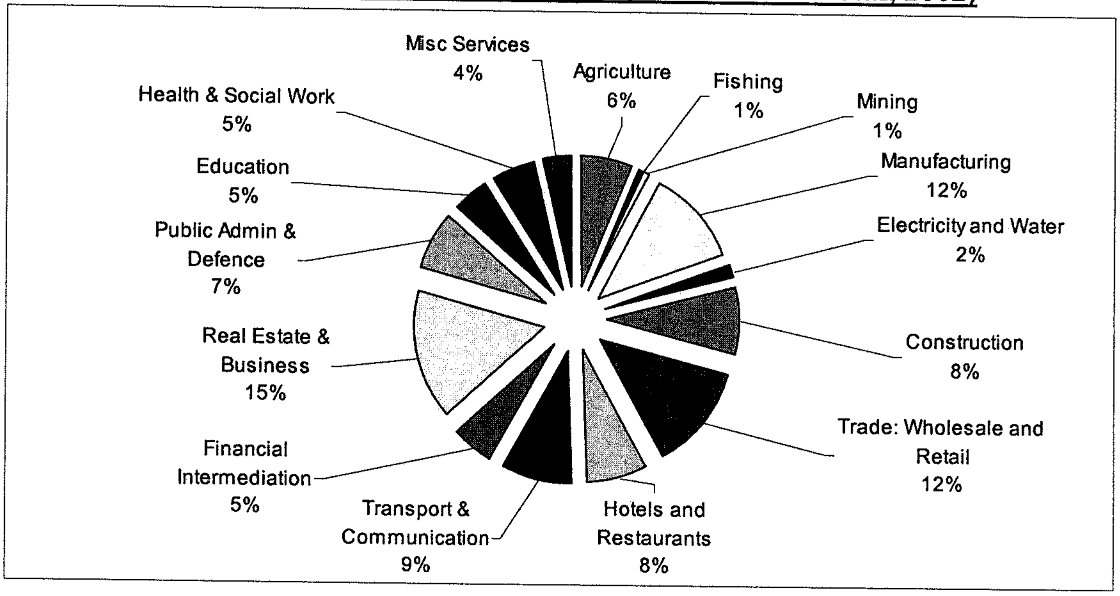
Source: National Statistics Service (2003): 23

A worrying trend presented in Table 4.1 is the rising public debt, which increased steadily in absolute terms in the period 1993-2002. Although its magnitude relative to the country's GDP has hardly changed over recent years, a large public debt combined with a lack of long term planning for payments such as benefits and pensions could pose a considerable threat to fiscal solvency.

In terms of economic structure, years of structural adjustments have now diversified the traditionally agrarian Greek economy. Figure 4.3 illustrates the proportion of Greek GDP accounted for by the country's different industries. The primary sector's (agriculture, fishing, mining) diminished importance (accounting for 8 per cent of GDP total) is obvious. Greece's (light) manufacturing industry is also shrinking as a result of increased exposure to international competition. The services sector continues to expand, with real estate, retail, construction, transport and communication (incl. shipping) and tourism (hotels & restaurants) taking a dominant place (Eurostat, 2003a). It is noteworthy that despite a series of high profile privatisation deals, the public sector still holds strong; 7 per cent of the country's GDP is accounted for by the public administration sector, with state-owned firms also dominating the mining, and utilities (electricity and water) sectors. The public sector is still disproportionately large by EU standards, though arrangements for the privatisation of a number of state corporations are at an advanced stage[58].

[58] The Commercial Bank of Greece and the Natural Gas Authority have been scheduled to be privatised in 2004. Olympic Airlines and DEH (Public Electricity Service) are due for 2005.

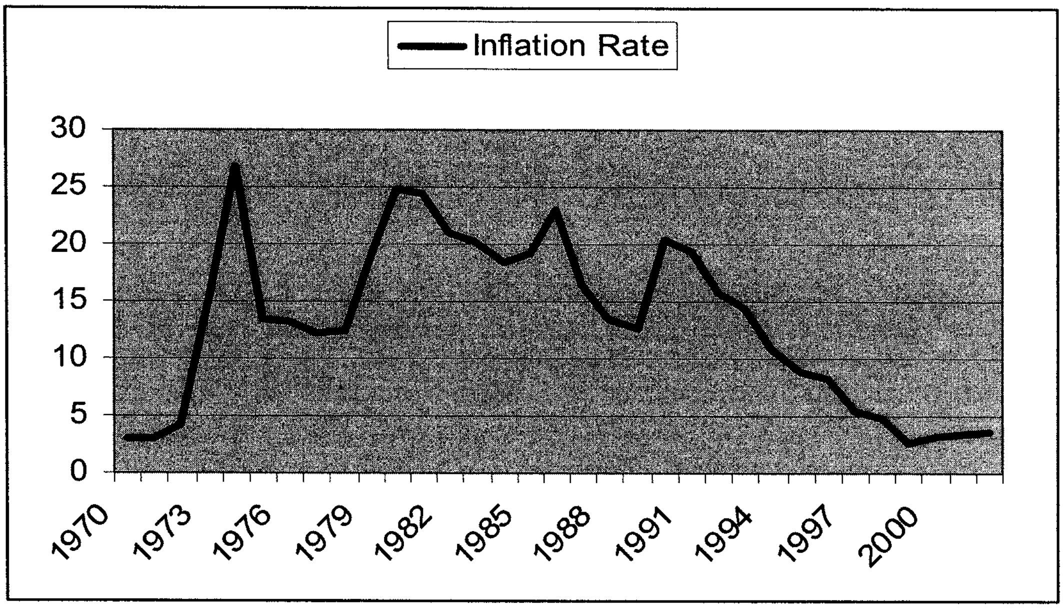
Figure 4.3 – Greece: Industrial Output (share of GDP total, 2002)



Source: Eurostat (2003a)

Inflation has been a recurring problem for the Greek economy; this created an aversion towards investing in liquid assets and a preference for the housing market and government bonds. This preference was more prevalent in the period leading up to the mid-1990s. The systematic decline of inflation rates (Figure 4.4) for most of the 1990s, revitalised investor confidence and led to an outbreak of activity in the Athens Stock Exchange (ASE), culminating in the period 1998-2000. Poor regulation and inflated share prices led to a sudden decline of ASE's general index in late 2000. Though it has still not reached pre-2000 levels, the presently better regulated ASE represents a viable finance option for large sized firms.

Figure 4.4 – Average Annual Inflation Rate (CPI) 1970-2002



Source: Compiled using data from the National Statistics Service (2003): 20

Business confidence has been boosted by the introduction of the euro, which promises low interest rates and makes cheap capital borrowing available to both consumers and firms alike. A study by the Hellenic Banks Association (HBA, 2002) suggests that by October 2001 Greek interest rates had largely converged with European averages but, according to the HBA, there was still scope for further reductions. Household borrowing has also increased dramatically over the past three years[59], which in combination with government spending in infrastructure, and capital inflows from the EU's Community Support Framework have revitalised the market. The overall positive picture is in contrast with persistently high unemployment (close to 10 per cent at present), attributed to structural causes (Table 4.2).

[59] Household debt represented 26.2% of GPD in late 2003, which is still comparatively lower than the EU average (49%) (HBA, 2003; Ta Nea, 2004)

Table 4.2 Employment in Greece 1998-2002

	1998	1999	2000	2001	2002
Total Workforce (thousands)	4,445.7	4,463.2	4,437.4	4,362.2	4,369.0
Unemployed (thousands)	478.5	523.4	491.1	444.7	420.1
Unemployment level (%)	10.8	11.7	11.1	10.2	9.6

Source: National Statistics Service (2003): 5

The structural changes blamed for unemployment are the de-industrialisation process[60], the pressure to meet tight fiscal criteria for EMU, the changing composition of the Greek labour force (both in terms of age and skill) as well as the arrival of significant numbers of foreign immigrants. The presence of greater numbers of foreign workers has caused a decline of wages (especially for low-skilled jobs) and thus made certain types of jobs unappealing to the native population.

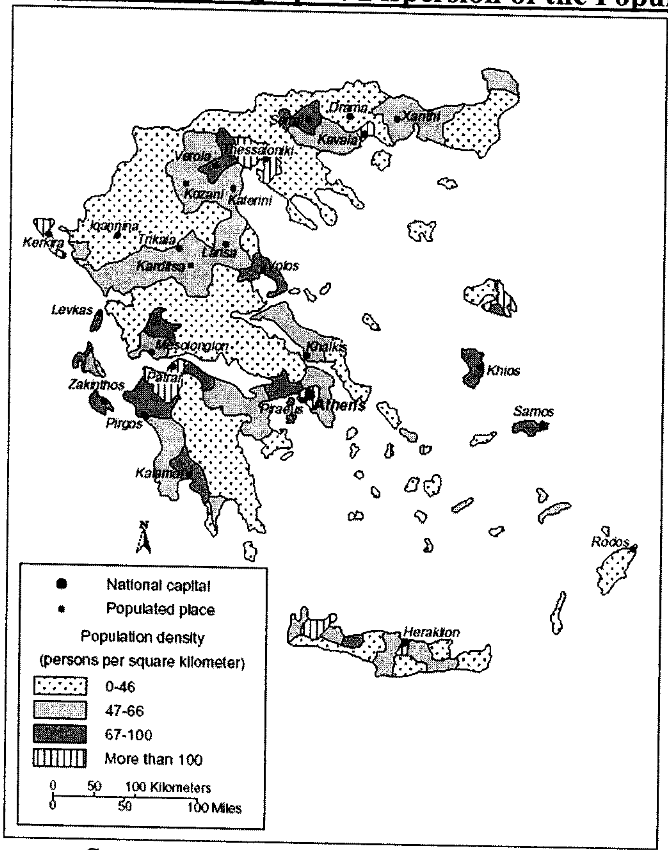
- *Human resources (spatial issues, composition, education)*

The vast majority of the population resides in urban centres, with the cities of Athens and Thessalonica accounting for almost 50 per cent of total population. The external emigration of the late 1940s and the 1950s was followed by a long-term trend of internal migration on a massive scale. The current imbalance between the city and the periphery is a relatively recent occurrence, which took place during the rapid development and industrialisation of Greek urban centres (mainly Athens and Thessalonica) during the 1950s and 1960s. According to Alogoskoufis (1997)

[60] Until the early 1990s there were a number of nationalised firms that dominated the Greek industries of construction, textiles and even manufacturing. After the customs union of 1992, increased competition from international firms drove a number of large and inefficient organisations out of business. The negative effect on employment was aggravated further due to the fact that a number of private businesses relocated their production operations (off-shoring) to more cost-efficient production environments.

throughout the 1970s successive government efforts attempted to limit the urbanisation trend and support the periphery, as many Greeks abandoned the countryside in favour of urban centres. In present day Greece, the bulk of the population resides in the four major Greek cities, namely Athens, Thessalonica, Patras and Heraklion (Figure 4.5). The rural areas that managed to maintain a significant population base are generally those with a relatively developed tourism industry (Aegean and Ionian islands) and/or a modernised agricultural sector (Central and South-Western Greece). In the last two decades though this trend has been reversed; at present Greek labour is considered to be one of the least mobile in the EU, a trend encouraged by complex employment legislation. Indeed, Tsipouri (1991) argues that the low geographical and institutional mobility of personnel inhibits directly the process of technological transfer and diffusion.

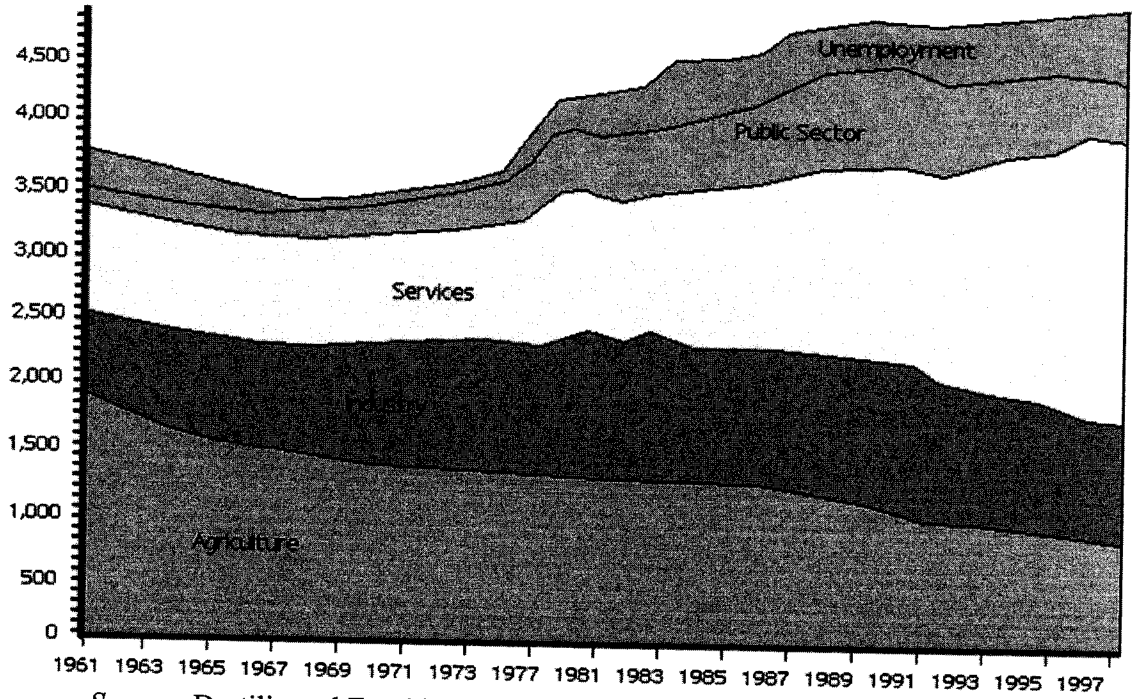
Figure 4.5- Greece: Geographic Dispersion of the Population.



Source: The Library of Congress (2003)

The composition of the Greek labour force in terms of occupation sector presents a mixed picture (Figure 4.6). The percentage of the Greek labour force occupied in the agricultural sector has been steadily declining in the past four decades but is nevertheless uncharacteristically high compared to EU standards. Observing Figure 4.6, the persistence of a high number of public sector workers is a testimony to Greece's 'socialist' political heritage after two decades of centre-left governments. The services sector grew considerably in the post-dictatorship era and is still growing today. Industry followed a rising trend up until the mid 1980s driven by nationalisation and heavy external borrowing. The bankruptcy of a number of big industrial corporations (Softex, AGET-Hercules Construction, Piraiki-Patraiki Textiles etc) along with the privatisations of the 1990s and the relocation of the production operations of other firms abroad (Nireus, Intracom, Petzetakis, DIEKAT, Nikas, etc) gave rise to unemployment towards the second half of the 1990s. Greece's current economic prosperity could not have materialised without the availability of a cheap labour force comprising mainly of economic immigrants from Eastern European countries (Economist, 2002a).

Figure 4.6
Greece: Labour Force Composition, 1961-1997



Source: Dertilis and Fragkiadis (1999: 21)

At the same time, by most international measures the Greek labour force is a highly skilled and educated one. That is, Greece scores high if one equates 'education' to 'literacy' and disregards the ability of the educational system to meet the needs of the economy. A defining characteristic has been the lack of state funding for education[61]; in 1999 Greek public expenditure on education represented just 3.5 per cent of GDP

[61] Bernard Shaw famously remarked that "*the modern Greeks' education has always been rudely interrupted by schooling*"

(Schmidt, 2003) – a figure that is the lowest in the EU (EU15). In modern Greece educational achievement is perceived to be synonymous to professional success[62] and Greeks set very high standards for their offsprings' education. That is an education, which although nominally 'free' by constitutional accord, is in practice hardly without a direct monetary burden to Greek households. The average Greek household spends a relatively high part of their disposable income on education[63]. As a result, literacy rates in Greece are as high as 97 per cent and the majority of the population (particularly in the urban centres) is able to communicate in at least two languages (EIU, 1998). Even though the overwhelming majority of young Greeks attend state schools, most also complement their language, science and arts skills in privately owned educational institutes. The proportion of Greek high school leavers that intend to progress to higher education is among the highest in Europe (EIU, 1998).

Comparing Greece's educational performance with that of other EU countries trailing below the EU average would be a helpful indication of relative labour force competencies. Looking at young graduates (25-35 year olds) is perhaps a good indication of the immediate effects of the education system on the labour force's skill profile. Table 4.3a presents data which appear to suggest that secondary educational

[62] Though unemployment among university graduates (which in 1998 stood at 22 per cent among 25-29 year olds) would seem to support that this is not a view shared by most Greek employers. The paradox between the exceptionally high demand for higher education on one hand and the relative certainty of prolonged unemployment among young graduates on the other is explored in detail in a paper by Liagouras, Protogerou and Caloghirou (2003). Liagouras, Protogerou and Caloghirou (2003) argue that the paradox can be explained by the low demand for high-skilled workers and the failure of Greek universities to meet the needs of the economy. The Economist's (2002a) survey of Greece, in a section entitled "*A bit more neocracy please*" attributes high unemployment among younger people to prevalent cultural values regarding age and experience.

[63] OECD (2004) data suggest it is the highest among the EU15. According to Kanellopoulos and Pascharopoulos (1998) the aggregate expenditure of households in education is roughly half of what the state spends on education.

attainment in Greece is more successful than either Portugal or Spain. Table 4.3b though suggests that consistent improvements among young graduates have only been achieved in upper secondary education and unlike Ireland, Spain or Portugal there has been no relative increase in the number of tertiary education graduates.

Table 4.3a – Population percentage that has attained at least upper secondary education (2002)

(%)	Age group				
	25-64	*25-34*	*35-44*	*45-54*	*55-64*
Greece	50	72	58	42	28
Ireland	60	77	65	51	37
Portugal	20	35	20	14	8
Spain	41	58	46	31	18

Source: OECD (2004c)

Table 4.3b –Educational attainment of the 25- to 34-year-old population (1991-2002)

(%)		1991	1995	1998	1999	2000	2001	2002
Greece	*Below upper secondary*	n/a	36	31	29	28	27	*26*
	Upper secondary and post secondary non tertiary	n/a	38	45	46	48	49	*50*
	Tertiary education	n/a	26	24	25	24	24	*24*
Ireland	*Below upper secondary*	46	36	33	28	27	24	*23*
	Upper secondary and post secondary non tertiary	35	37	37	44	43	42	*41*
	Tertiary education	20	27	29	28	30	33	*36*
Portugal	*Below upper secondary*	79	69	72	70	68	67	*65*
	Upper secondary and post secondary non tertiary	12	17	17	18	19	19	*20*
	Tertiary education	9	14	12	12	13	14	*15*
Spain	*Below upper secondary*	60	53	47	45	44	42	*41*
	Upper secondary and post secondary non tertiary	24	21	21	21	22	22	*22*
	Tertiary education	16	27	32	33	34	36	*37*

Source: OECD (2004c)

Quantitative data though present only part of the picture; in fact the most lasting influence of the Greek educational system on the ability of the workforce to innovate and accept new ideas is a qualitative one. Years of underfunding meant that constant economising has had an effect on the quality of teaching; this reflects both on scarcity of resources (few hours of teaching, time rotation, absence of labs and equipment, outdated textbooks) and educational philosophy (inappropriate pedagogy, haphazard instruction, ill-conceived assessment). This has had a very negative effect on the quality of education provided[64] and makes international comparisons of similar qualifications less accurate.

All the above, combined with a strong attachment to the study of Greek antiquity, indeed one that is apparent in all stages of education irrespective of discipline, have resulted in an educational system valuing knowledge of authorities over critical ability and creativity[65]. There is no other stage of the educational process where this is more obvious than the Pan-Hellenic Exams (examinations used as a benchmark of ability for university admission purposes, in a fashion similar to the British A-Levels). So great is the demand for tertiary education (and the universities' inability to meet it) that typically the last two (increasingly three) years of secondary education are devoted to preparing for the Pan-Hellenic Exams. The assessment rationale of the Pan-Hellenic Exams sets one strict criterion; the students' ability to reproduce

[64] A full appraisal of which is beyond the scope of the present thesis.

[65] The Greek educational system suffers from what is often referred to in common parlance as "papagalia" (translating as "parrotism" or "one's ability to sound as repetitive as a parrot"). Papagalia is still actively endorsed as a learning method; partly because it is less demanding in terms of educator workload during delivery and partly because pre-defined knowledge is easier to assess.

information. As a consequence it rewards memory skills; while good memory is certainly a desirable quality in university, arguably critical and creative aptitude is just as (if not more) important – a set of skills that it does very little to assess[66], let alone cultivate. Such an educational approach also contributes to a perception of knowledge as a static, absolute concept. The above educational shortcomings are pervasive and over the years have contributed to a national culture that is averse to novelty.

Nowhere else are these shortcomings more apparent than in tertiary education. Universities are available in most major Greek cities and are meant to cater for the higher education needs of students nationally. While it is true that many academic departments have high standards of teaching and research the overall picture is one of economic stagnation[67] and disorganisation characterised by strong union militancy, a detachment from pragmatic industry needs and perpetual nepotism[68]. Few university degrees are tailored to industry needs although in a recent survey of Greece appearing in the Economist (2002a) it is argued that this is rapidly changing. An indirect indication as to the ineffectiveness of Greek universities to improve productive capacity comes from the work of Asteriou and Agiomirgianakis (2001). In their econometric study seeking links between formal education and economic growth in Greece, Asteriou and Agiomirgianakis (2001) found strong causal relationships in all

[66] Possible exceptions from the 'memory criterion' are the subjects of 'creative writing' and inclusion in the exams of original exercises in maths and science subjects (though they are few and far apart).
[67] The Greek constitution dictates that the state should provide the opportunity of free education to all Greek citizens. Modern policy makers have realised that in the case of higher education this is an unrealistic goal. If Greek universities are to reach EU standards they are faced not only with the legislative hurdle of the constitution but also with a strong-minded public opinion.
[68] Characteristics that apply uniformly across public-sector organisations in Greece.

educational levels except higher education. Astonishingly, Asteriou and Agiomirgianakis (2001) present evidence suggesting an inverse relationship between amounts spent on tertiary education in Greece and overall economic growth[69]. The labour market's lack of demand for highly skilled workers (Liagouras, Protogerou and Caloghirou, 2003) is at least partly to blame.

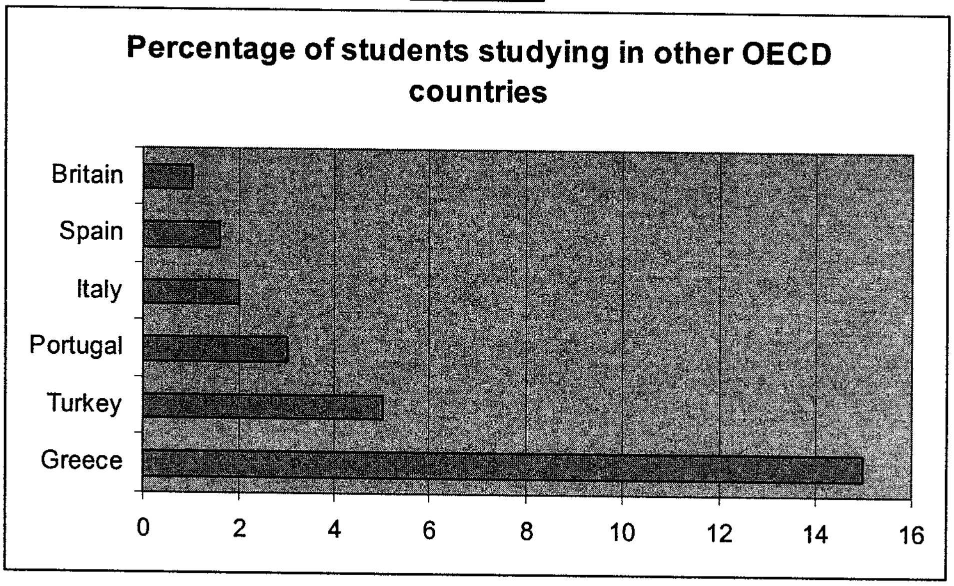
The research output generated by universities in Greece is also small when compared to international standards[70] as indicated by a recent study on economics research by Kalaitzidakis, Mamuneas, and Stengos (2001). Greek universities fail to cope with domestic demand for higher education. With state-sponsored higher education being chronically underfunded, Greeks complement their education on a range of privately-held vocational and science colleges[71]. A large number of Greeks also receive higher education abroad; indeed according to the Economist (2002a) the instance of the phenomenon is the highest amongst OECD countries with as much as 15 per cent of Greek university students studying abroad (Figure 4.7).

[69] This may of course have less to do with the internal performance of Greek universities and may be a reflection of the economy's greater need for capital inputs. It is nevertheless interesting as an indication of the relative importance of secondary education.

[70] According to Liagouras, Zambarloukos and Constantelou (2004: 8) in 2003 Greece had a 'publications per million of inhabitants' ratio that was 68 per cent of the European (EU15) average. Among EU15 only Portugal had a lower ratio (at 50 per cent).

[71] With the exception of foreign language and arts colleges these institutions are merely 'tolerated' by the state; they are not regulated by state authorities, thus diplomas and certificates issued by such colleges are mostly denied official recognition. It is currently felt that the official recognition of these institutions would serve to undermine state-owned universities. Since many of these colleges either collaborate or are jointly owned and managed by international universities (mainly from the U.S. and Britain), lack of recognition could be interpreted as a form of protectionism for the country's nationalised education industry.

Figure 4.7

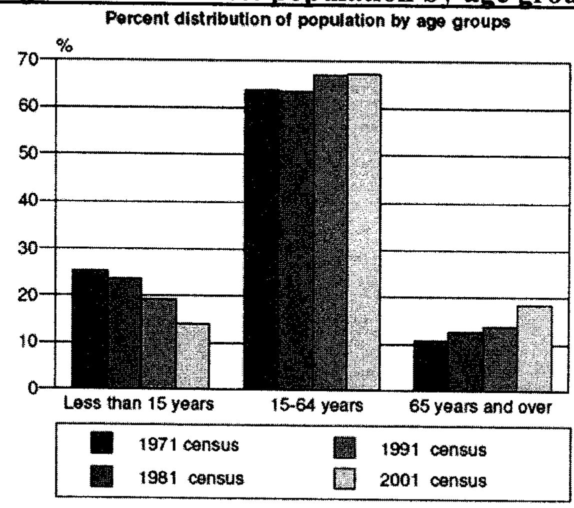


Source: Economist (2002a: 19), based on OECD data

In terms of labour efficiency, an international study by Maudos, Pastor and Serrano (2003) reveals that productivity growth in Greece has been among the lowest exhibited in OECD members. Maudos, Pastor and Serrano (2003) estimate labour efficiency for the period 1965-1990 among OECD members utilising estimates of the effects of financial capital, labour inputs and human capital on output (GDP) and TFP. In their resulting index of labour efficiency Greece scores second last and performs even worse when the proxy for human capital is included in their model. A study commissioned by the National Bank of Greece (Mylonas and Malliaropulos, 2004) however, observes increases in labour productivity (annual input/output ratio) during the period 1999-2003 that are higher than the EU15 average. The authors of the study attribute this increase to the one-off influx of immigrant workers rather than human capital or technology-related TFP gains.

Another feature of the Greek labour force is the overall increase of its age (Figure 4.8). This is a common characteristic of developed societies, where rising living standards and economic transformation have had a negative effect on birth rates. There are growing concerns that low birth rates will eventually reduce the size of the workforce and consequently place a high burden on public finances. Government will not only be collecting less taxes; it will also have to sustain an ever-greater number of pensioners (Figure 4.8).

Figure 4.8 – Greece: population by age groups



Source: National Statistics Service (2002)

The overall increase of the workforce's age has implications for its approach towards technology. Souitaris (2001) in his research of Greek SMEs, found that older SME managers are more likely to be found in non-innovative firms. The overwhelming prevalence of older individuals in management posts with a responsibility for investment also reflects on its technological diffusion competencies. Older Greek managers and entrepreneurs are used to dealing with a volatile business environment which presented few rewards for risk-taking. Hence, from a cultural viewpoint they are in favour of conservation and may in principle decide against technological adoption of appropriate technologies.

- *Infrastructure*

The physical infrastructure of Greece is poor when compared with the average standards of its European Union partners. The poor quality of its transport and communications is thought to be a contributing factor to its high trade deficit (EIU, 1998); it has not only hindered local entrepreneurial activity but it has also discouraged foreign investors. Furthermore, it has been inhibiting the development of broad economic networks and the facilitation of systemic linkages conducive to innovation. This is why most of the European Union funds available to Greece are spent on transport and communications infrastructure projects. Much progress has been made in this area, especially as pressure mounted ahead of the 2004 Olympic Games in Athens. The modernisation of the national road and rail network is progressing at a rapid pace. Large transport infrastructure projects have already transformed the greater Athens area. Currently, the focus of transport infrastructure projects is the north of the country with particular emphasis in improving physical links with Greece's Balkan neighbours. Liberalisation in the communication sector has also yielded positive results. Fierce competition is driving prices down and improving the quality of service, albeit at a much slower pace than that experienced by Greece's EU partners. There is still much scope for improvement as both transport and communication services are still considered amongst the most expensive and inefficient in the EU (OECD, 2002). In an economic survey of the country the OECD (2002) concludes that their effective liberalisation is central to Greece's long-term growth prospects.

Moreover, R&D expenditure is amongst the lowest in European Union countries (discussed in §4.3.3) and public initiatives for the encouragement of R&D have materialised relatively recently in the form of the General Secretariat for Research and Technology (GSRT) of the Ministry of Development. GSRT oversees innovation actors and even funds innovative companies to perform R&D. Its current success record is mixed; in one of its recent reports (Logotech, 2001b) concludes that such activities are fragmented and are heavily dependent on state funding.

4.2 Greek Technology Policy

Government policy on innovation has only recently existed in a co-ordinated manner and its overall direction has been greatly influenced by the orientation of the European Union's technology policy. Indeed, policies drafted at the European level directly translated into commensurate actions at the national level. A number of Europe-wide technology policy initiatives have been motivated by the European Commission's realisation that;

> *"firms' capacity for innovation and support for it from the authorities, were essential for maintaining and strengthening [...] competitiveness and employment*" (EC, 1995: 2)

The importance of technology, both original and as a product of transfer, for the survival of Greek firms in an increasingly globalised environment has more recently been recognised in policy directed documents such as the Greek Government's *Greece in the Information Society* (1999) and in numerous documents by the GSRT (2001, 2003, 2004).

Tentative attempts to create a technology policy framework had to follow an input-oriented approach. Such attempts concentrated on capital inputs in education, the purchase of equipment and basic research in order to improve skills and infrastructure and encourage the adoption of modern technologies. The realisation that Greece lagged behind in the diffusion of several key technologies for development, meant that diffusion has traditionally taken priority in technology policy. As a consequence much of innovation expenditure still funds the adoption of existing technologies rather than the generation of original ideas.

Prior to the 1980s the Greek approach to technology policy had been characterised by lack of co-ordination and the absence of a holistic long-term strategy. A single, coherent policy with regards to technology had been an elusive target; multiple government ministries had taken on the task to promote innovation and the spread of technology. Such a responsibility overlap is, in some areas, still prevalent today[72]. Each one of these ministries formulates policy in its respective area, spurred on mainly by EU technology policy schemes which are (only sometimes) hastily adjusted to match their own agenda. In the period 1980-1990 technology policy was characterised by numerous bold declarations, promises and optimistic predictions amounting to little more than plain 'statements of intent'. Notable exceptions are the establishment of the short-lived Ministry for Research and Technology (1984-1986) and the general overseer body that is still around today, the General Secretariat for Research and Technology in 1985[73].

The law 1514/85 outlined the institutional framework for the development of scientific research and was a legal cornerstone for Greek technology policy (GSRT, 2004). The law established for the first time in Greece the role of a 'researcher' as distinct of that of other employees in tertiary education. As a consequence, it opened the possibility of research funding and facilitated the measurement of research output in Greek universities and other research institutions. Importantly, it also defines '*the country's economic interest*' as the ultimate aim of technology policy. Hence, by definition, economic growth and development became the driving motive of technology policy. Choosing what policy to implement though proved challenging.

[72] The Ministry of Education, The Ministry of Development, the Ministry of Industry, the Interior Ministry and the Ministry of Economy and Finance are directly involved in funding R&D, training personnel and facilitating the spread and assimilation of new technologies (Appendix 5).
[73] Which consequently fell under the jurisdiction of the Ministry of Industry (1986-1993) and then the Ministry of Development (1993 to present).

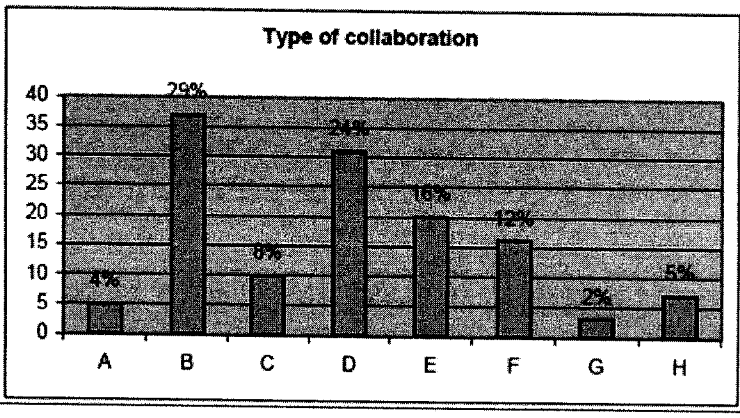
Before the 1990s different policy actors largely perceived the institutions under their authority to operate in isolation and drew policy accordingly. The globalisation and liberalisation of the Greek economy that ensued in the 1990s increased the competitive pressure among enterprises mainly in the industrial and services sectors, and less in the agricultural sector. The lack of adequate (country-specific) statistics and accompanying academic analysis on the field also hampered the formulation of effective technology policy. In a rapidly developing economy (as was Greece during the 1990s) an initial technological needs analysis, followed by specific policy responses, could provide a stepstone upon which a broader technology policy framework could evolve. This was attempted by the Development Ministry's "EPET I" (1990-1992) (Research and Technology Executive Programme), "STRIDE Hellas" (1992-1994) and "EPET II" (1994-1999) which sought to "*upgrade the research and technology infrastructure and develop important research products*". EPET I embarked on the direct funding of basic scientific R&D projects deemed of relevance to the Greek economic and social reality, industrial R&D (manufacturing, construction and especially ICT) and University research. A major initiative was the establishment of *technology parks* to act as contact conduits between the research community and industry. EPET I aimed to encourage technology transfer and diffusion via the creation of technology parks and technological and human resource databases. In addition it carried for the first time, the responsibility for the assessment of Greek technology policy and the provision of new overall policy recommendations. STRIDE Hellas was essentially an extension of EPET I, with a renewed emphasis on interaction between research actors and industry. EPET II however, set more ambitious targets. EPET II aimed to support S&T activities particularly in innovation-intensive industries (ICT, biotechnology, new materials) (GSRT, 2003).

In addition, prior to the 1990s no concrete provision for the facilitation of a national innovation system had been made, where institutional actors from education, research, the state and industry could come together to foster R&D and diffusion. Policy making in the area involved measuring the yield of inputs onto specific outputs while ignoring underlying mechanisms as outlined in systemic approaches to innovation (such as the ones of Lundvall, 1992 and Peterson and Sharp, 1998). The GSRT aimed to change this situation by assuming a central role in coordinating the evolution of a national innovation system. EPET I, STRIDE Hellas and EPET II contributed some way into alleviating this but basic inefficiencies with regards to networking still persist.

Studies on the Greek economy's capacity to innovate have concluded that knowledge flows are obstructed by weak links between private firms and the scientific innovation-generating institutions (Logotech; 2001b). For example, according to Kastelli and Tsakanikas (2000) in 1993 private firms financed only 1.4 per cent of the Universities and Public Research Institutes expenditure on R&D.

Kastelli and Tsakanikas (2000) refer to cross-institutional cooperation in innovation and diffusion as *research joint ventures* (RJVs). Kastelli and Tsakanikas (2000) performed a survey of all joint research activities that took place in the period 1985-1996 in Greece which included at least one private sector participant. Based on data from the National Documentation Centre, they identify a total of 158 such projects and they mention that more than 70 per cent of them were funded or aided in one way or another by either EPET I, STRIDE Hellas, or EPET II. A break down of their findings according to the type of the collaboration is presented in Figure 4.9. It is apparent that the most common type of RJVs is the one occurring among firms and universities (29 per cent), followed closely by three-way co-operations between firms, universities and research centres. Collaboration among firms is very low at 4 per cent, an indication of the absence of market influences (either demand or supply side) to the innovation process. Figure 4.9 highlights the importance of co-operation between more than two innovation actors. Universities are present in the majority of collaborations (85 per cent) which is to be expected, since they are the main R&D generating institutions. It is interesting that relatively few of the RJVs (12 per cent) involved a direct interaction between primary innovators (research centres) and technology consumers (firms). However, Kastelli and Tsakanikas (2000) found even such collaborative activities are heavily depended on government funding; for as much as 73 per cent of private firms involved this was a one-off activity.

Figure 4.9 – Research Joint Ventures: Breakdown by Type of Collaboration



A: Firm-Firm collaboration, B: Firm-University collaboration, C: Firm-University-Other, D: Firm-University-Research Center, E: Firm-University-Research Center-Other, F: Firm-Research Center, G: Firm-Research Center-Other, H: Firm-Other. (Data available for 128/154 projects).

Source: Kastelli and Tsakanikas (2000: 11)

So far policy appears to have delivered modest results; it has failed to generate the momentum necessary for a sustainable, market-driven and market-oriented national innovation system. The GSRT (2003a) acknowledges the need for policy adjustments based on the experience of EPET I, STRIDER Hellas and EPET II. It has formulated a new Executive Programme of Competitiveness (EPAN) to run in the period 2000-2006 on funding provided by the EU's Third Community Support Framework. According to the GSRT (2004);

"The general policy directions of EPAN 2000-2006 are:

(i) the enrichment of the productive core with new business activities that are knowledge intensive;

(ii) the creation of new businesses headed by researchers and research institutions;

(iii) the support of new businesses R&D efforts through consultancy services (technology parks)

(iv) attract foreign firms to the usage of Greek R&D infrastructure;

(v) the support of the activities of research and technological development for competitiveness."

It is interesting that diffusion did not deserve a special mention in the GSRT's latest priorities but was rather overshadowed by a more general need to achieve 'competitiveness'. There is also a shift of emphasis towards R&D activities and the greater involvement of firms in the innovation process. Especially encouraging is the aim of promoting linkages between Greek research generating institutions and foreign affiliates. While these are positive steps, a lot is still left to be desired. Policy making in the area is new and, it seems, in constant search of purpose. As indicated by the conclusions of Kastelli and Tsakanikas (2000) and is further elaborated in the sections that follow (see '*A Technological Map of Greece*'), the efforts to improve the firms' absorptive capacity and create a system of institutional innovation actors have so far had little success.

The fact that the overall direction of technology policy is initiated at the EU level is also a mixed blessing. Arguably EU-directed programmes are useful in stimulating interest and activity on the field that would otherwise receive little attention or, judging by the experience of Greece prior to the 1980s, no attention at all. Their contribution in providing general direction towards proven effective technology policies is notable. Perhaps most importantly, such programmes provide much needed funds in the form of the Community Support Framework for structural adjustments that poorer EU countries such as Greece could not afford otherwise.

However, the dependence on EU-funded policy schemes has meant that the efficiency of technology policy may have been compromised by the EU's agenda for '*ever greater economic and political integration*'. The technological and developmental needs of member states may, at times, have come second to the need for European integration. At present, EU technology policy fosters R&D and diffusion through the development of pan-European innovation institutions aimed not only at the creation of national innovation systems but also at the long-term development of supranational synergies among member states. Undoubtedly, the development of cross-boundary technology linkages would be a positive development. Nonetheless, this integrationist agenda meant that technology policy in Greece has been gearing institutions to promote a national 'innovation system' to the extent that it belongs to an EU-wide supranational innovation system.

It is the priority assigned to these supranational synergies that has called for uniform, blanket approaches to EU policy schemes (with the possible exception of the regional aspects of such programmes[74]). However, EU technology policy is frequently based on assumptions and is fine-tuned according to the economic reality prevalent in the core Western-European economies. These are countries with developed economies, long-established scientific and R&D traditions, with efficient accompanying institutional frameworks which are at the forefront of technological development. Their requirements with regards to the assimilation of the very latest technologies and the sustainability of their current thrust in the generation of innovative ideas place them at a very different position to that of poorer countries in the European periphery. This is the main thesis of Liagouras, Zambarloukos and Constantelou (2004) who argue that technology policy should be primarily motivated by country-specific needs. Liagouras, Zambarloukos and Constantelou (2004) review the behaviour of market and policy actors in Greece in the emerging fields of biotechnology and e-commerce. They found that (EU funded) EPET II schemes had very little success in stimulating collaborative projects, adoption and R&D in neither field (biotechnology nor e-commerce). They believe that this failure comes down to the different characteristics of the Greek pharmaceutical, agricultural and IT sectors as opposed to the rest of Europe. Operations in the aforementioned industries in Greece are largely confined to the later stages of production (packaging, marketing, distribution) where there is little scope for innovative activity. Liagouras, Zambarloukos and Constantelou (2004) conclude that the mere imitation of technology policies of economically advanced countries could prove totally inappropriate for countries in

[74] Even region-specific programmes tend to group together European regions on the basis of common characteristics. This is arguably an approach that hardly accounts for national specificities.

economic transition. They propose that intermediate economies should focus on upgrading productive capacities while stimulating domestic demand for innovations.

It is indeed true that technology policy in Greece has until now placed great weight on the supply-side of technology; whether one looks at educational attainment, research output or the adoption and assimilation of existing technology, *supply* has been the main concern. If one judges by the targets of EPET I, Stride Hellas, EPET II and EPAN, little thought has been placed on the cultivation of demand for highly skilled workers, productivity-enhancing organisational technologies and relevant research output. In the author's opinion the importance attributed to highly advanced technologies (such as biotechnology and e-commerce) and other knowledge intensive fields has been particularly misplaced. Such technologies may hold great potential for the creation of substantial markets in the future but currently account for only small proportions of modern economies. Important though they may be, there are far more pressing technological needs, not on the sidelines on economic activity, but at its very centre. The following sections underline that Greece lags significantly behind in the diffusion of much older and important "stepstone[75]" technologies. This is why an effective technology policy must be centred, first and foremost, on domestic needs.

4.3 A Technological Map of Greece

In the present section an attempt is made to present an almost-comprehensive picture of technology related activities in Greece and their impact on the general economy.

[75] The term "stepstone" is used as a reference to them being the basis upon which the diffusion of more recent technologies can occur.

Though wide in its focus the present 'technological map' aims to be brief and concise, reflecting current reality (data, mechanisms and policy) related primarily to diffusion. Frequently the lack of data and insightful studies in the field limited the scope and depth of analysis. For a lack of better options, at times the focus is directed by what data is available rather than what would ideally be the most appropriate information to present and analyse.

4.3.1 Technology Transfer in Greece

The transfer of technology in the form of technological inputs from abroad is even more important for a rapidly growing economy such as Greece. The post-war development of the Greek economy has largely been based on know-how and technologies which were imported from abroad. The main sources of technological inputs into the Greek economy have been the transfer of technology in the form of foreign direct investment, technological licensing agreements and the import of capital goods (Souitaris, 2001). Korres (1995) argues that slow technical change is often thought of as one of the defining features of the Greek economy in the last four decades.

Essentially, Greece has been a purchaser of internationally produced R&D without producing itself any of its technological requirements. In fact, according to Korres (1995) domestic R&D activities were virtually non-existent prior to the 1950s and this is particularly true for the private sector. An important feature is that enterprises have never been a source of either supply or demand for national R&D activities.

This only started to change (albeit at a very slow pace) after MNEs became a permanent feature of the Greek economy.

Economy-wide technology transfer is difficult to measure. The nature of technology itself (what to record), in conjunction with deciding how to practically gather such data have compounded the problem. Should one measure patent licenses and royalties or the flow of financial capital intended for technological purchases? Should these be measures of inputs or outputs? As is common in the present field of study, these are relatively new questions and have no resolute answers.

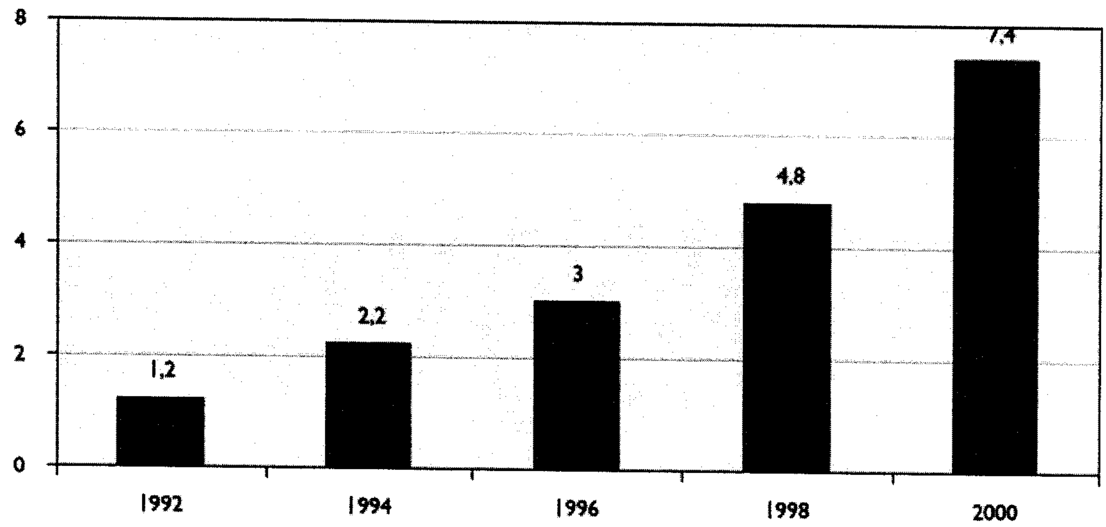
According to Godin (2002) *the technological balance of payments* (TBP) is accepted by international organisations such as the OECD and the UN as a potent measure of technology transfer. The TBP is a useful measure as it quantifies the transfer of patents, licenses and other forms of know-how across international borders. However it is not without misgivings. The TBP records only those transfers of technology that give rise to financial flows; it is nearly impossible to keep track of the movements of technology, which is financially 'invisible'[76]. Unfortunately in the case of Greece data on the TBP is not available; the OECD's (2004b) *Main Science and Technology Indicators*, reports TBP data for most OECD member countries, but not Greece. The Eurostat's (2004c) *Science and Technology Indicators for the European Research Area* (STI-ERA) also lists TBP for Greece as non available. Since neither the National Statistics Service, nor the National Bank of Greece (the two main information gatherers for the Greek economy) record such flows, TBP data for

[76] e.g. cross-border cooperation between researchers, technologies transferred internally by MNEs

Greece is unavailable. If one is to take this lack of data as an indication of the low importance attributed to technology statistics in Greece, this could also act as a confirmation of the haphazard treatment of technology policy in general.

The only data available on international technology payments is with regards to the trade of advanced technologies, often termed 'high tech goods'. These are technological goods or services that have been recently invented and are traded in innovation-intensive industries including the electronics, advanced materials and the pharmaceutical industries. High-tech goods could act as a measure of the economy's ability to generate innovations with an international appeal and thus as a broader indication of the domestic innovative capacity. Data provided by the GSRT (2003a) point to a systematic increase in the export of such goods (Figure 4.10). GSRT's data suggest an increased importance of hi-tech goods in the country's exports; this could be interpreted as a manifestation of the creation and evolution of a comparative advantage in producing such goods. However, the international trade performance of high tech goods presents only part of the overall picture and hardly allows for firm conclusions to be drawn.

Figure 4.10 - Exports of High Tech Products as a Percentage of Total Exports



Source: GSRT (2003a:7)

Having had a limited glimpse on the overall level and momentum of the transfer of technology to and from Greece one should at the very least have a brief look on the main actors and mechanisms for technology transfer. The primary actors for the introduction of novel ideas from abroad are perhaps unsurprisingly, multinational corporations. Braconier et al (2001) and EORG (2001) have demonstrated empirically that this is certainly true for most Europe, including Greece. At the same time, MNEs originating in Greece are also responsible for the export of technological goods and services. Due to the lack of disaggregate data on TBP the scale of this transfer, either way, is impossible to describe precisely.

Vernon's (1966) product cycle theory suggests that in an economy in transition such as Greece, multinational corporations would initially have little interest in the transfer of technology. One of the assumptions made by Vernon (1966) is that technology is a substitute for expensive labour in production. Only after economic development has pushed wages up to a level closer to that of the MNE's country of origin does the transfer of technology make sense. With real wages in Greece slowly converging towards the EU average (INE, 2001[77]) the motivation for the transfer of production technologies may become greater. Added to that, the need for product and/or service adjustments to local market conditions is bound to grow as a function of the local market's relative importance for the MNE, thus prompting specialised R&D. However, Greece's relatively small industrial base (where the product cycle theory would have immediate applicability) calls for cautiousness. The existing evidence presents a mixed picture. Data supplied by the OECD (2003) suggests that the share of foreign MNE subsidiaries in the total industrial R&D expenditure was just 6 per cent in 1999. At the same time, during 2002 28 per cent of Greek patents at the European Patents Office were the result of co-operation with foreign co-inventors (OECD, 2003).

Detailed empirical studies certainly portray MNEs as technology transfer agents with a benevolent effect on the host country's technological capital, provided some conditions are met. Papanastassiou (1999) conducted an empirical analysis of technology transfer and production strategies of MNE subsidiaries in Greece, Belgium, Portugal and the United Kingdom. In a sample of 145 companies, Papanastassiou (1999) found that in all four countries, MNE subsidiaries relied overwhelmingly on imported technology from abroad while local sourcing of technology was rare. Papanastassiou (1999) found that whether an MNE subsidiary

[77] INE (2001) acknowledges a marked long-term increase in real wages but also mentions that real wages in Greece are among the lowest in the EU-15 (second last only to Portugal).

was importing a technology or developing it locally depended on the existence of production operations within the subsidiary. Subsidiaries which managed to establish production facilities in the host country were likely to commit to a local R&D department. Added to that, Papanastassiou's (1999) econometric analysis suggests a negative relationship between imported technology and product development. Hence, one could argue that once an MNE's presence in the host country has reached such a maturity as to allow for local strategy differentiation, MNEs may become more than simple channels for the transfer of technology but could also foster innovation. Anastassopoulos (2003) also touches briefly on the subject. Indeed, Anastassopoulos (2003) found that MNE subsidiaries in Greece have higher R&D to sales ratios compared with other domestic firms in the same industries.

It seems reasonable to presume that on a much smaller scale, national public and private research and consultancy organisations also play a role. Consultancies can intermediate for the transfer of technology to and from Greece while also fostering human resource and R&D co-operation. Such consultancies may include firms which specialise in professional training and ISO-standards quality certification. At present only a handful of such firms operate in Greece. Nevertheless, the currently low demand for organisational innovations (Liagouras, Zambarloukos and Constantelou, 2004; Logotech 2001a) make it unlikely that these actors have a great share on influencing the transfer of technology. Small firms in Greece are reluctant to source technology directly from abroad. They face high costs and uncertainty arising from different regulatory environments and may even be discouraged by communication barriers. It is usually firms with a critical mass and which operate nationally and sometimes internationally that engage in technological licensing agreements. A positive development is the envisaged creation of a set of pan-European technology transfer initiatives (Kastelli and Tsakanikas, 2000), which promise to provide open access to international pools of both product and process technologies.

4.3.2 Technology Diffusion in Greece

The diffusion of technology in the economy has profound implications for productivity, economic structure and long-run economic growth. Indeed there is evidence for this link relating specifically to Greece and the diffusion of ICTs. Daveri (2002) in his study seeking links between growth and the diffusion of ICTs in the EU, singles out Greece and Ireland as the only EU countries benefiting substantially from adoption of such technologies. Specifically, Daveri (2002) shows that the rapid diffusion of ICTs in Greece during the second half of the 1990s is associated with higher total factor productivity. The above indicates the great opportunity for economic growth in Greece posed by technological diffusion. Unfortunately, the slow diffusion rates and the persistent diffusion gap in key technologies for productivity (including ICTs) means that such an opportunity remains untapped.

Detailed empirical studies on the diffusion of specific technologies in Greece are scarce. For instance, there is no single study detailing the country-specific determinants of diffusion. The only glimpse of information into economy-wide technology adoption trends comes in the form of international diffusion estimates by the UN. The United Nations (UN, 2001) *Human Development Report* includes data for Greece on the diffusion of internet hosts, telephone lines and electricity. The overall diffusion level of these technologies can give us a good general indication of the innovation receptiveness of the economy. In terms of overall diffusion competency and innovative capacity the UN brands Greece a '*potential leader*' (UN, 2001: 45). Indeed, at the global level, Greece is in UN's (2001) ranking table among the 30 most technologically advanced countries.

However, at the European level such comparisons are less flattering. Comparing the diffusion levels in the above technologies with those achieved by countries with a similar economic performance could help identify possible trends. UN data indicate that Greece is faring behind its EU partners (UN, 2001), even those that are at a comparable developmental stage (Ireland, Spain and Portugal) as presented in Figure 4.11. The diffusion lag is more profound with regards to the diffusion of the internet (internet hosts[78] per 1000 people). Though given the current growth pace of internet adoption in Greece[79], this gap is rapidly closing. Ireland's performance in the diffusion of the internet is notable; arguably the technology has a higher perceived relative advantage there as Ireland's English-speaking population is likely to receive greater dividends from using the English language dominated World Wide Web. Indeed, Buhalis and Deimezi (2003) cite the lack of content in the Greek language as a significant barrier to consumer internet adoption in Greece.

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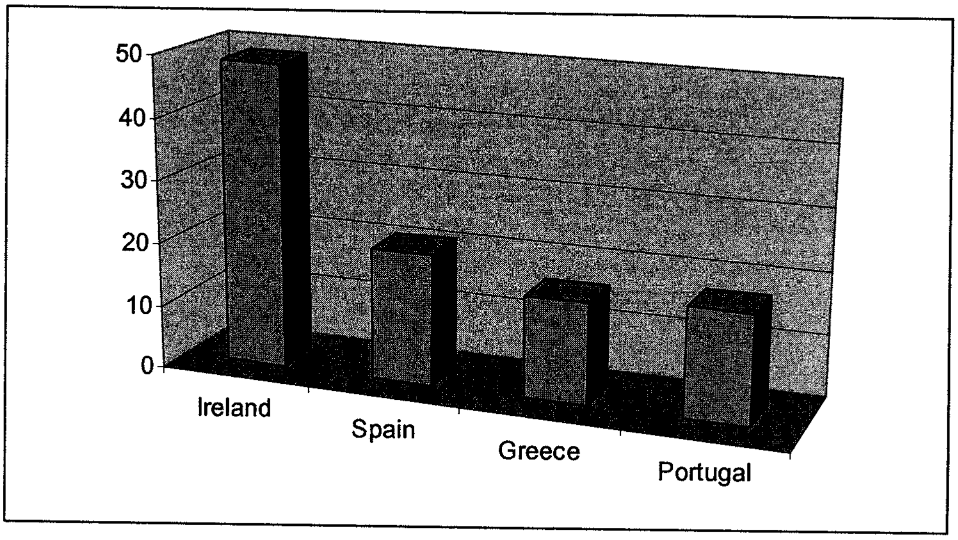
[78] The term "internet host" refers to a computer system connected to the Internet - either a single terminal directly connected or a computer system that allows multiple users to access network services through it. Internet hosts are a preferred unit of measurement of internet diffusion over internet users or internet usage because they reflect a financial commitment to the technology and they are easier to quantify. In addition according to UN (2001) data on internet hosts is more reliable.

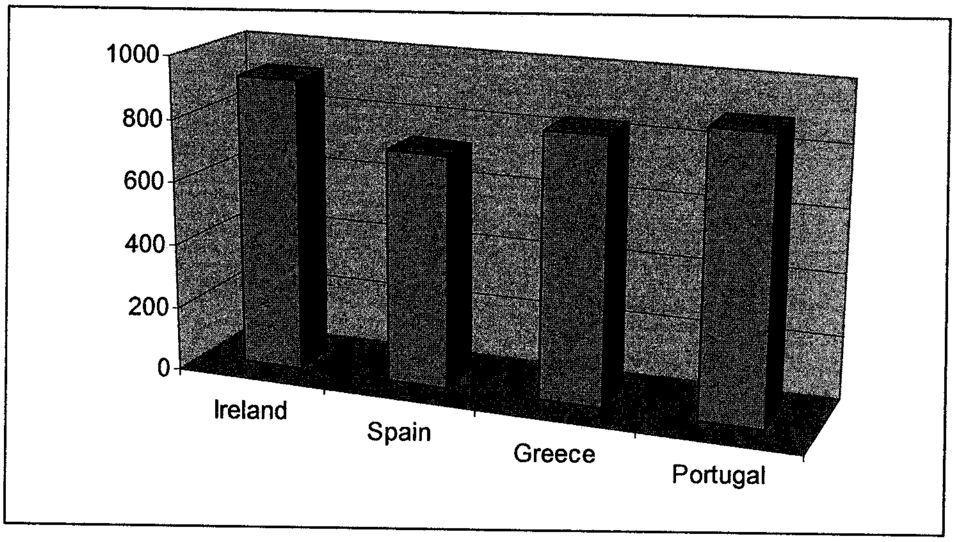
[79] According to ESIS (2001) internet adoption growth in Greece in 2000 was 55 per cent per year for individual adopters and 28 per cent per year for firms.

Figure 4.11 - Internet, Telephone and Electricity Diffusion

Internet Hosts per 1000 people, 2000

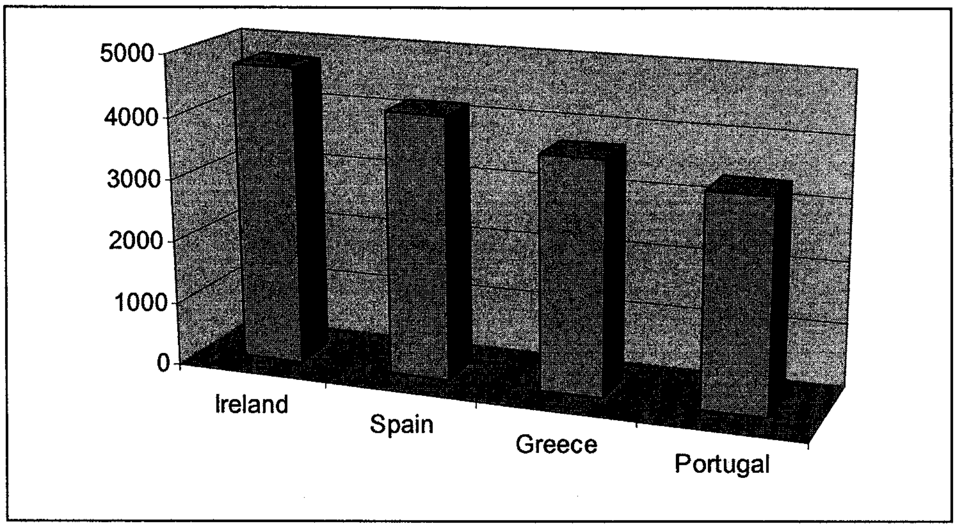


Telephones (landline and mobile) per 1000 people, 2000



Electricity Consumption (kilowatt-hours per capita), 2000

(continued...)



Source: Compiled using UN (2001: 48) data

The situation is different for the diffusion of telephones and electricity. These technologies demonstrate a comparatively satisfactory level of diffusion. In theses cases however, consumer trends (rather than corporate diffusion) had quite possibly more to do with accelerating diffusion. Buhalis and Deimezi (2001) point to the fact that the evolution of mobile phones as fashion accessories played a major role in the technology's diffusion in Greece. The liberalisation of the Greek telecoms industry and consequent price decreases in service charges was probably also a contributor to the overall diffusion of telephones both fixed-line and mobile. Past studies on diffusion have shown that the level of market concentration is one of the main determinants of economy-wide adoption (Nasbeth and Ray, 1974; Romeo, 1975), with lower concentration being advantageous.

A better understanding of the economy's absorptive capacity can be achieved by means of an outline of the most significant country-specific barriers to adoption. Theory suggests that the demand for technology goods is primarily influenced by the technology's relative advantage versus its cost (Rogers, 1983). Indeed, in the case of Greece, firm-level surveys by Bartzokas (2000) and Logotech (2001b) conclude that the financial cost of the technology is a significant barrier. Bartzokas (2000) maintains that most businesses in Greece often lack adequate internal financial resources to invest in technology. Logotech's survey results point to cost and perceived risk as the two greatest inhibitors. Bartzokas (2000) also cites lack of assistance by major customers as an inhibitor. Bartzokas' survey findings appear to validate the author's earlier assumption about the importance of demand; indeed insufficient or uncertain demand was by far the most significant barrier to adoption. The lack of an established R&D tradition (discussed in the next section) and accompanying institutions is also seen as an obstacle to the dissemination of innovations.

An understanding of the major factors (facilitators/inhibitors) determining adoption could lead to effective policy that increases the overall conduciveness of an economy to technology. Policy makers have undertaken attempts to overcome such barriers and encourage the diffusion of innovations in two main ways; by enhancing communication among actors through the establishment of technology parks and by using financial capital inputs to promote what have been thought as high-yield technologies. Influenced by information spreading theories hinging on the importance of communication, it was believed that the diffusion process would be accelerated if innovation actors were to be situated in close geographical proximity. Hence, small clusters of innovative companies or research actors were developed, in a community arrangement dubbed a 'technology park' or sometimes a 'science park' (terms used interchangeably). Technology parks act as interfaces between technologically-inept SMEs and innovators thus effectively becoming diffusion and innovation catalysts (Kelessidis, 1998). As separate from this main orientation, Castells and Hall (1994) argue that technology parks are also meant to promote reindustrialisation, regional development and the creation of synergies. Castells and Hall (1994) see technology parks as a new form of industrial organisation and definitely one that is demanded by Castells' on-going ICT 'revolution'.

The degree to which technology parks fulfil their main purpose and act as conduits for technology is debatable. Bakouros, Mardas and Varsakelis (2002) point out that international empirical studies have failed to produce a unanimous judgment. On one hand some studies found that technology parks have had an important effect on the creation of diffusion synergies not only among research actors and industry but also among firms themselves. On the other hand, other studies argue that in many cases such synergies fail to take place and even when they do, their performance is much lower than the expected. In fact Bakouros, Mardas and Varsakelis (2002) point to studies that portray technology parks as little more than prestigious real estate developments and relegate them to mere "*high tech fantasies*" (Massey et al., 1992; cited in Bakouros, Mardas and Varsakelis, 2002: 124). Based on their review of relevant empirical literature, Bakouros, Mardas and Varsakelis (2002) argue that the success of technology parks is conditional to their population and spatial issues (geographic proximity of innovative actors and park density).

There are currently three technology parks in Greece; the Science and Technological Park of Crete (STPC), the Technological Park of Thessaloniki (TPT) and the Science Park of Patras (SPP). In their survey of Greek technology parks, Bakouros, Mardas and Varsakelis (2002) mention that all three parks are relatively new (running for less than a decade) and have managed to attract only a handful of firms. Kelessidis (1998) reviews the operations and challenges of the TPT. He reaches the conclusion that the TPT has been successful in establishing a:

> "*demand driven, network based strategy for fulfilling the role of the intermediary... [TPT]... offers a range of services, from technological information dissemination, to technology brokerage, to partnership establishment, to linking industry and research.*"
> (Kelessidis, 1998: 10)

This could be taken as indication of exceptional performance for one of the Greek technology parks. However, Kelessidis (1998) does not make reference to specific performance indicators that could substantiate such a claim. While such services are indeed offered, it does not necessarily follow that they are used by firms. In their survey on the presence of linkages, Bakouros, Mardas and Varsakelis (2002) report a total absence of research and diffusion synergies among firms in all three technological parks. Collaborative technological activities are non-systematic and involve firms and the local university. Firm interactions at any level were minimal and involved mostly non-technology related market transactions. This is direct evidence of the parks' failure to deliver the promised outcomes. Bakouros, Mardas and Varsakelis (2002) attribute such failure to the young age of Greek technology parks. Furthermore, they apportion part of the blame on to the technology parks' currently unrestrictive letting policy. They believe that a letting policy which discriminates in favour of innovative firms should have a positive effect on collaborative efforts. Whatever, the specific reasons for the technology parks' failure, there are strong indications that the relative lack of insight into the specific characteristics of Greek firms and the traditional imitation of Western-European models is ultimately culpable. In the words of Bakouros, Mardas and Varsakelis (2002):

> "*...the development of the Greek science parks do not distinguish them from the developments in other science parks as reported in literature, even though Greece does not belong to the core technological countries of Europe.*"
>
> (Bakouros, Mardas and Varsakelis, 2002: 127)

The predominance of very small firms, the lack of incentives to locate at a technology park and the absence of substantial research output among innovation actors are factors distinctive of Greece. These differences against the more technologically advanced European countries justify why the development of technology parks in Greece should merit special attention. Technology parks in more developed countries aim in the creation of synergies in R&D (i.e. the *creation* of innovations). Given that at this stage very little of this activity takes place in Greece and in Greek firms in particular (see §4.3.3 and §4.4.4), diffusion synergies[80] may be a more realistic goal. The implementation of technology parks in Greece has been yet another manifestation of a narrow-minded philosophy prevalent in technology policy.

Finally, input-centred technology diffusion schemes have targeted specific industries (e.g. the ADAPT Initiative for manufacturing firms[81]) or firms with common characteristics (e.g. EOMMEX's GO-Online scheme for SMEs). They strive to promote diffusion through subsidies for the purchase and subsequent implementation and adjustment of technology to the firms' structures. While ADAPT succeeded its initial aims (Appendix 4), Go-Online has set ambitious targets which it has yet to meet. As elaborated further in Chapter 5, the emphasis on finance may have been misplaced given the current availability of cheap financial capital. The empirical part of the thesis attempts to establish the diffusion determinants that are relevant to the Greek business environment by means of a case study.

4.3.3 R&D Activity in Greece

An outline of the historical and current trends in the development of innovations in Greece is useful in indicating the general technological competencies of the Greek economy. It is also a good indication of the ability of firms within this context to be aware of technological developments, and consequently be in a position to make decisions about them. Godin (2002), in his detailed review of technology indicators

[80] e.g. synergies between technology importers, educators and technology consumers

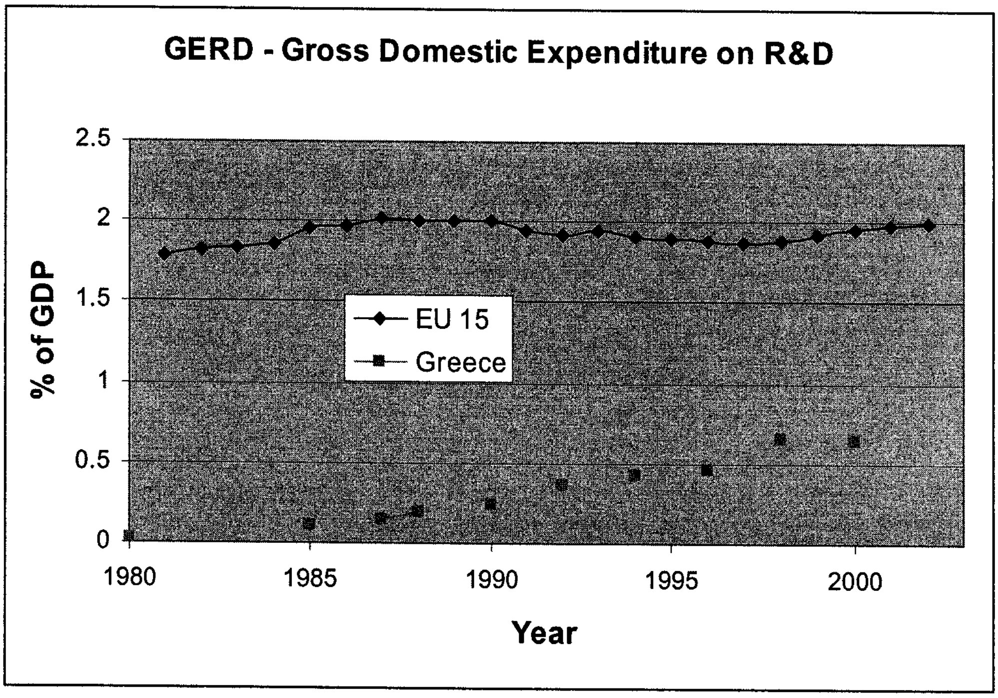
[81] The Adapt Initiative aimed to transfer advanced manufacturing practises to a number of smaller Greek manufacturers. The programme stands out from other similar initiatives in that it achieved its original objectives in their entirety. See correspondence in Appendix 4

identifies *expenditure on R&D* (as an input measure) and *the number of patents* (an output measure) as the most commonly used economy-wide indicators. Primary data on R&D activity in Greece are available through a multitude of sources including the Greek Ministry of Development, the GSRT, the National Statistics Service, the OECD and Eurostat.

Research and development activities are thought to be central to the diffusion process; Julien (1998) points to evidence that firms who engage in R&D are more likely to adopt an appropriate technology early and maximise their benefits in doing so. This is achieved by means of technological scanning; actively developing innovations necessitates perfect information about the availability of and barriers to the adoption of existing technologies. Moreover, R&D activities contribute to the overall conduciveness of the economy for technologies as they encourage familiarisation with the operation and qualities of advanced technology. Evidence provided by both individual empirical studies (Panousis and Kymperi, 1999; Kastelli and Tsakanikas, 2000; Souitaris, 2001) as well as large scale surveys (Logotech, 2001b; OECD, 2004b) suggests that Greece has been a chronic under-performer in terms of research and development.

One broad measure of R&D investment is the country's Gross National Expenditure on Research and Development (GERD). Figure 4.12a presents a comparison of Greek GERD to the European average (EU 15) as a percentage of GDP. It is evidently a comparison suggestive of chronic underfunding, though there are some tentative signs of convergence from 1990 onwards (see also Appendix 3).

Figure 4.12a – GERD in the EU and Greece, 1980-2002



Source: Compiled using data from Eurostat (2004a)

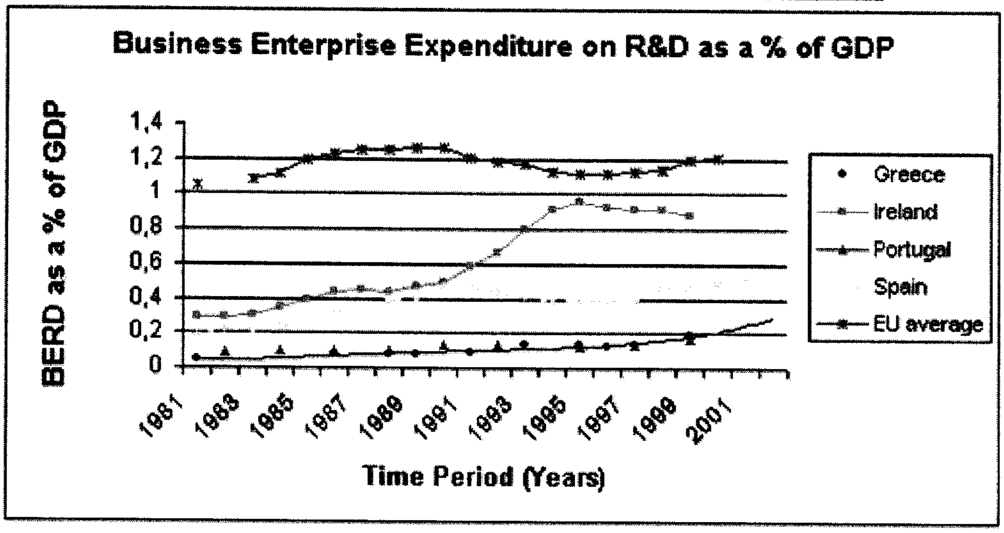
To make matters worse, at present the vast majority of GERD is traced back to the government. The private sector has had little involvement in innovative activity as shown by Greece's Business Expenditure on Research and Development (BERD) (Figure 4.12b). Figure 4.12b demonstrates that at the European level, Greece does not measure up to comparison in terms of BERD even against countries of otherwise similar economic performance such as Spain and Ireland. It is interesting though that Portuguese firms appear not to take a significantly greater interest to research and development expenditure than Greek firms. The fact that it is on its public sector, one of the most inefficient in the OECD (Afonso, Schuknecht and Tanzi, 2003[82]), that

[82] Afonso, Schuknecht and Tanzi (2003) measured the performance (*"the outcome of public sector activities"*) and efficiency (*"the outcome relative to the resources employed"*) of the public sectors of

Greece places its hopes for technological development on serves to highlight the country's technological deficiencies.

Added to the above, those firms that do innovate tend to do so autonomously. The Ministry of Development's *National Innovation Survey in Greek Enterprises* (Logotech, 2001a) found that Greek firms regardless of size or industry develop innovations in isolation from their environment. This is in spite of the importance attributed by policy makers in the creation institutional linkages by means of technology parks.

Figure 4.12b - BERD as a percentage of GDP, 1981-2001



Source: National Documentation Centre (2001)

23 OECD countries on the basis of numerous performance indicators on the government's core functions. In both counts (performance and efficiency) the Greek public sector was the worst performer.

It is also interesting that multinational enterprises are increasingly contributing to Greek R&D expenditure. Theory suggests that as MNE presence in a host reaches maturity the need for local strategy differentiation increases the impetus for localised R&D. Table 4.4 demonstrates an increasing trend in the participation of MNEs affiliates to the generation of innovations.

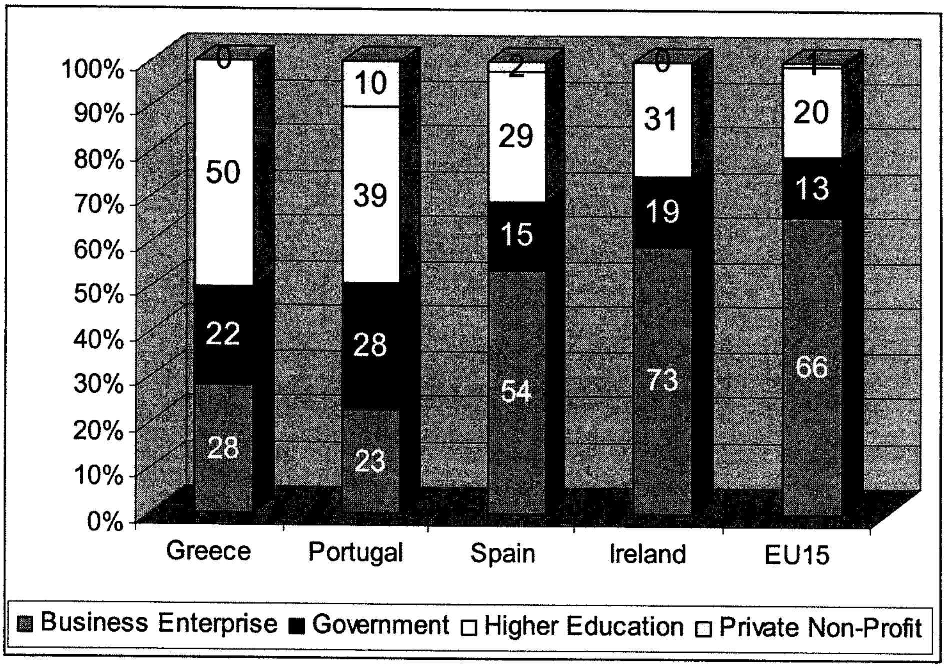
Table 4.4 - R&D Expenditure of Foreign Affiliates

	1996	*1997*	*1998*	*1999*
Million Dollars, 2004 Prices	5.9	7.1	n/a	14.4
Proportion of Enterprise R&D Expenditure	3.4%	2.6%	n/a	4.5%

Source: OECD (2004b: 50)

The main actors of domestically produced R&D in Greece are the Universities, the so-called Public Research Institutes (PRIs) and a small number of firms (both domestic and increasingly, multinationals) which have reached a critical mass and are in a position to finance in-house R&D.

Figure 4.13 – R&D Expenditure Breakdown by Institutional Sector



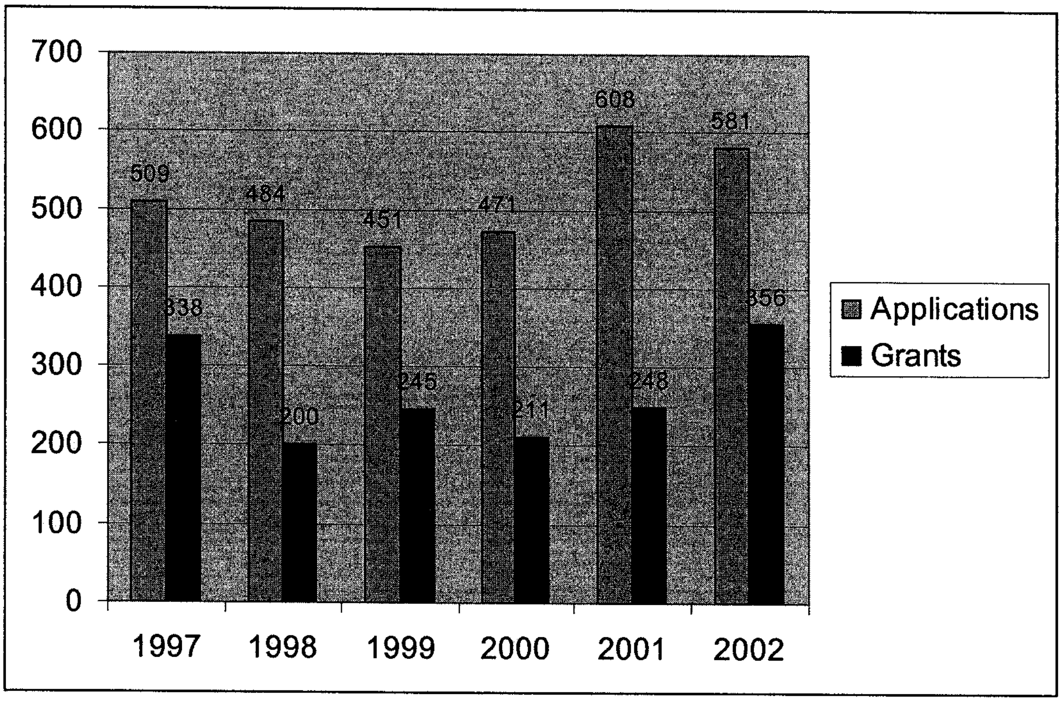
Source: Eurostat (2003b: 20)

Figure 4.13 presents a comparison of relative institutional sector expenditure in R&D in Greece, Portugal, Spain, Ireland and the EU15 average. Earlier figures indicated that R&D activity in Greece is at a quantitative disadvantage (in terms of expenditure) in comparison with its EU partners. Figure 4.13 draws attention to the structural or qualitative deficiencies of R&D in Greece. The emphasis placed on higher education in Greece is not only the greatest in the countries mentioned in Figure 4.13 but it is also uncharacteristic of any other EU country. It raises the possibility that the inefficiency of Greek Universities may be largely to blame for the overall low research output.

Another commonly used measure of R&D activity intensity is the number of patents registered at any given year. This is based on the assumption that when someone applies for a patent they have developed an edge technology they deem worth protecting. The number of registered patents is arguably a less objective measure of R&D intensity than GERD or BERD since patents may often be the result of chance innovation. Not all patents are equivalent units of analysis as they are bound to be the result of unequal efforts and are likely to have a varying impact on the economy. Additionally, very few patents eventually translate into marketable products or services. At the same time though, in spite of these shortcomings they are perhaps the only research output deliverable. Useful conclusions can be drawn about general trends but still one ought to consider the above limitations when interpreting patent statistics.

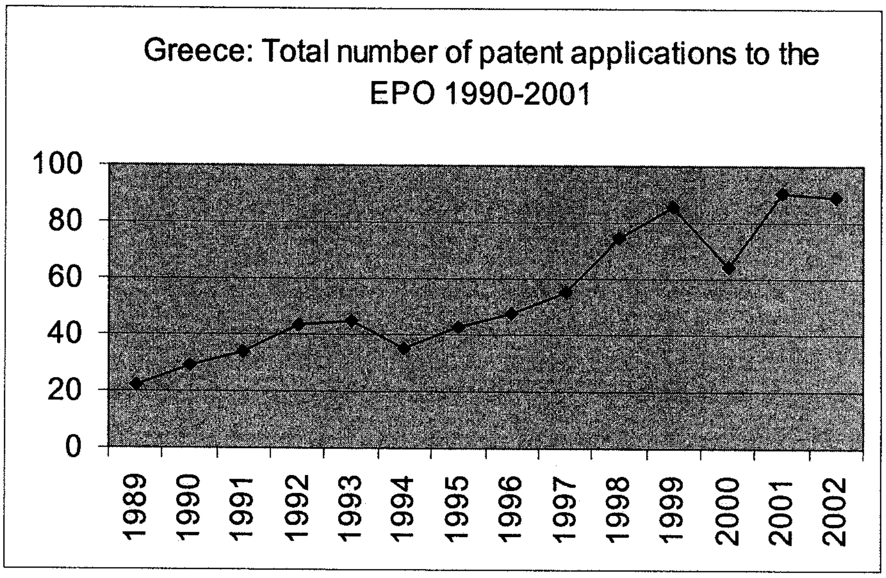
In the last few years, a considerable number of applications were submitted to the Greek patenting office, the so-called Industrial Property Organisation or OBI. Figure 4.14a presents the number of applications submitted per year as well as the number of applications granted. There does not appear to be a particular trend in the data for the period concerned (1997-2002), except for a notable increase in activity in 2001.

Figure 4.14a – Number of Patent Applications to the OBI, 1997-2002



Source: Compiled using data from OBI (2003: 12)

Figure 4.14b – Number of Patent Applications to the EPO 1990-2001



Source: Compiled using data from Eurostat (2004a)

At the same time, Greek firms would also apply for protection of their ideas to the European Patents Office (EPO). The absolute number of Greek patent applications to the EPO is so small (Figure 4.14b) so as to preclude any safe conclusions. Notwithstanding the previous statement, Figure 4.14b demonstrates a steady rise in patent applications during the second half of the 1990s that could hardly be attributed solely to chance innovation. Furthermore, the number of patents registered at the EPO is not as much of a measure of innovation in Greece as it is of the willingness of Greek firms to protect their innovations abroad. Therefore this upward trend may be one reflection of the development of Greek MNEs. It is possible that as outward-FDI from Greece increased during the mid-1990s[83] (see Table 4.6), the impetus to protect innovations internationally increased accordingly.

The overall conclusion considering both expenditure and patent data is that despite the relatively low investment and uncoordinated technology policy there are some initial signs of improvement. It would be inappropriate though to draw firm conclusions; existing data is insufficient to suggest a long term trend that is distinct from cyclical factors.

[83] For a detailed review of the evolution of multinationals originating in Greece see Kamaras (2001).

4.4 Greek SMEs and Technology

4.4.1 Characteristics of Greek SMEs

Small and Medium sized Enterprises (SMEs) are firms with limited assets and turnover. They tend to be studied collectively as it is thought that they have common characteristics and face similar challenges. An assumption internal to the study of SMEs is that sectoral and other forms of heterogeneity are less prevalent in firms of small size. According to the European Commission (1996), a company that is classified as an SME must fulfil the following criteria;

(a) Employ less than 250 employees.
(b) Have either an annual turnover not exceeding 40m ECU[84], or an annual balance sheet total not exceeding 27m ECU.
(c) It must also be independent; i.e. not controlled by a larger organisation.

A common characteristic of all SMEs is that their capital base is often insufficient and their access to capital markets is limited. When SMEs seek capital, they often have to pay a lot more for it (Julien, 1998) thus being constantly at a disadvantage when compared for instance with multinational corporations who benefit from economies of scale. At the same time though, Julien (1998) argues that the absence of

[84] European Currency Unit (ECU), the precursor to the common European currency the euro. All references to ECUs in EU official documentation are meant to refer to euros as of 1/1/1999.

multiple layers of management is one of the real competitive assets of SMEs as they can take decisions quickly avoiding bureaucratic obstacles.

Arguably the Greek economic environment possesses characteristics which favour the survival of SMEs over larger companies. The sectoral skew of industrial structure towards agriculture, construction and wholesale and retail trade as well as a long standing climate of uncertainty meant that being small in Greece yields advantages. White (1982) found that the relative importance of SMEs is greater in industries with low capital intensity, are less vertically integrated and have a narrow geographic scope for their markets. EOMMEX (the Hellenic Organisation for Small and Medium Sized Enterprises and Handicraft) sees SMEs as being:

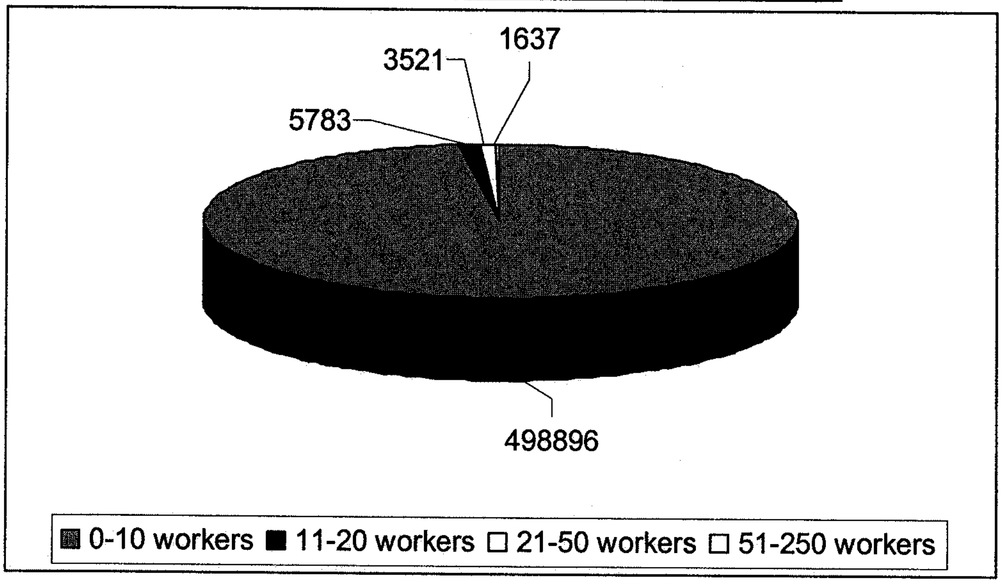
"...of vital importance to the economic development, the provision of employment and consequently the social coherence of Greece..." (EOMMEX, 2003: 2)

Kyriakoulias and Soumeli (1999) too argue that small and medium-sized enterprises are the country's predominant entrepreneurial model; they estimate that the share of their contribution to the GDP total amounts to about 40 per cent. The importance of SMEs in Greece is further underlined by the fact that firms employing 50 persons and below form 99.55 per cent of the total number of enterprises and employ 74 per cent of the labour force in the private sector (EOMMEX, 2003). EOMMEX (2003) data also show that SMEs in Greece provide almost 70 per cent of new jobs. In addition, EOMMEX (2003) indicates that more than half or 53.7 per cent do not employ any salaried workers. In total Greek SMEs employ over 1,695,000 people, of which

712,000 on average are on a payroll (EOMMEX, 2003). Large companies with over 250 employees represent only 13.5 per cent of total employment with 230,000 salaried staff (EOMMEX, 2003).

Based on the European Commission's definition of an SME and the last available enterprise-level data from the National Statistics Service (1995), the gross total of SMEs in Greece is 509,837. Figure 4.13 presents a breakdown of Greek SMEs according to size.

Figure 4.15 Number of Greek SMEs by Size (1995)



Source: Compiled using data from the National Statistics Service (1995)

As is obvious in figure 4.15, the dominance of the micro-firm (with less than 10 employees) is almost complete at 98 per cent. Such firms are typical family businesses where members of the family may contribute labour without being on a salary. In fact, Kyriakoulias and Soumeli (1999) argue that the predominance of the micro-firm is the characteristic that sets Greek SMEs apart from SMEs in most other EU countries. This is attributed to the fact that the main economic unit in Greece is the family; a prime example of a national culture influencing corporate aims and industrial structure. In addition, many of them operate in business fields which are not labour intensive. These characteristics mean that their financial incentive to substitute labour for technology is lower than that of other firms. This may explain at least partly the reluctance of small firms to adopt process technologies and be essentially product adopters.

Due to their size, SMEs have also constrained access to capital. Their capital reserves are in the majority of cases extremely low and are somewhat constrained by the generally small profit margins they have to operate at. The fact that many of them are family owned makes them risk averse and compromises their ability to become solvent quickly; the ultimate aim for these companies may not be expansion or the maximisation of profit but their bare survival and retention of the jobs they create.

Their small size limits their access to capital markets, such as for instance the stock exchange; indeed making an offer for sale in the Athens Stock Exchange is prohibitively expensive for the average Greek SME. Greece has traditionally faced monetary instability that made long-term borrowing a risky venture (Figure 4.2). On top of this family-ownership further compromises their potential for borrowing; very few companies have assets where long term loans can be secured against, as many Greek managers/proprietors prefer to own personally assets such as buildings. Greek participation in the EMU has created stable conditions which in turn facilitated an explosion in business (and household) borrowing (HBA, 2003). The availability of capital is becoming increasingly less of an obstacle to the adoption of technology. Table 4.5 summarises their main characteristics relevant to their adoption and innovation competencies.

Table 4.5 – Characteristics of Large, Medium and Small Greek Firms

	Large	*Medium*	*Small*
Access to Markets	national, international	national, local	local, national
Access to Financial Capital	stock exchange, retained profits, loans, venture capital	loans, retained profits	retained profits
Business Strategy	dynamic, rigid	dynamic	risk-averse

4.4.2 SMEs and MNEs: from adversaries to companions

It would only be a slight exaggeration to claim that at the end of the 1980s the Greek economy paid a closer resemblance to that of a post-communist country rather than one of its (then) EEC counterparts. Economic policy in the post-war era was marked by economic nationalism; industries in all sectors were heavily regulated, international trade was limited and economic development, it was thought, dependent primarily on state intervention. A decade of left-leaning governments after 1980 did little to liberalise the economy. The process of industrial deregulation initiated in

1989 created a legal and economic framework permissive (though not necessarily inviting) of the involvement of multinational enterprises. Movements of financial capital became more common and especially after the customs union of 1992, provided fertile ground for foreign direct investment. MNE involvement initially materialised in the form of joint ventures (mainly in retail and manufacturing) and consequently evolved into direct investment on wholly owned subsidiaries. UNCTAD (2004) data (Table 4.6) point to a steady and increasing flow of international investment. In his empirical research of the processed foods industry, Anastassopoulos (2003) observes that increasing inward-FDI has added to the competitive pressure of domestic firms.

Table 4.6 – Greece Inward-FDI and Outward-FDI 1999-2001

(Millions of dollars, 2003 prices)	*1999*	*2000*	*2001*
Inward FDI	571.8	1,121.7	1,589.3
Outward FDI	539.1	2,162.6	616.1

Source: UNCTAD (2004: 4)

As the Greek market becomes increasingly liberalised and globalised, competitive pressures add to the imperative to improve efficiency. Market prices are driven down and further cost reductions are necessary if a firm is to remain viable. For most of the 1990s Greek SMEs have witnessed the gradual erosion of their market share in favour of newcomer MNEs. During recent years, Greek SMEs in the retail and light manufacturing industries in particular[85] are driven out of business as they simply cannot compete with larger corporations (national firms, MNEs) which benefit from economies of scale, the labour/cost-saving qualities of technology adoption, their own R&D, international networking and even institutional linkages.

As far as MNEs are concerned, technological competencies are their competitive edge. Technology is more than a residual factor affecting their operations; it is very often at the centrepoint of their decision making process. Evidence from Greece suggests that technology decisions have a great effect on the general strategy of local MNE subsidiaries and even their ownership structure. Louri, Loufir and Papanastassiou (2002) conducted empirical research on the ownership decisions of MNEs involved in joint ventures with 216 Greek firms. Their results suggest that that the degree of ownership control by the multinational depends on the level of R&D intensity prevalent in their field of operations. Hence MNEs operating in R&D intensive industries, where technologies are ephemeral, are more likely to engage in majority ownership joint ventures. It could be argued that they thus maintain ownership control of edge technologies, with a view to maximise their market benefits. Likewise, where the rate of technological change is relatively slow and the capital requirements large, MNEs prefer to participate through minority ownership joint ventures. Baranson (1970) sees FDI in the form of joint ventures between multinational and local firms as particularly advantageous with regards to technology transfer. Based on the above, the currently upwards trend in majority-ownership joint ventures could be interpreted as a sign of greater localised R&D.

[85] For a review of the competitive changes faced by Greek retailing SMEs in recent years see Bennison and Boutsouki (1995).

Technological adoption is no longer a luxury but an imperative for an SME. This is particularly true since, unlike MNEs, they cannot benefit from the effects of economies of scale. Indeed, one of the major concerns of SME managers throughout the EU is their currently shrinking profit margin (Hughes, 2002). Economic theory assumes that small firms find it hard to both generate new innovations and adopt existing ones. The problem is worsened by the SMEs' aversion towards process technologies in general (i.e. they are product adopters) and organisational innovations in particular which are essential for productivity. The normative policy response to this apparent multinational 'onslaught' is to create and sustain a defensive posture for SMEs. Increasing 'competitiveness' is now the centrepiece of Greek industrial policy (IOBE, 2004), applied indiscriminately to both large and small organisations. It is the author's view that it is doubtful that government intervention, whatever its form, will be able to increase SME "competitiveness" to such an extent as to enable the currently backwards Greek SMEs to compete head-on with modern MNEs.

Apart from being a threat though, MNEs have presented Greek firms and indeed SMEs with considerable opportunities. MNEs have increased the size of current markets (indeed the economy in general) and created new ones. SMEs should refrain from 'fighting a lost battle'; competition and competitiveness should be left to firms of comparable size and resources. Rather modern SMEs can ensure their survival by aligning themselves vertically to MNEs, either as suppliers or as niche and local distributors. As MNEs in Greece are important innovation agents[86], local firms could benefit from market transactions and direct cooperation. Vernon (1966), Baranson (1970), Chen (1996) and Blomström and Sjöholm (1998) acknowledge the role of multinational companies as conduits for international technology transfer. In any case, establishing linkages with MNEs should become a strategic imperative for every small firm; linkage benefits are not only technology related; market transactions are also likely to lead to efficiency and quality improvements within SMEs that should in the long run make them more competitive. In contrast with competition-induced improvements which are brought about by means of *threat of exclusion*, MNE linkages could result in improvements by means of *positive incentives*. In other words, MNEs could show the way by enabling SMEs to harness the potential firm and market benefits of specific innovations (diffusion of information). This way SME managers can initiate change, based on an informed decision, one that is motivated by profit and efficiency incentives rather than lack of options.

4.4.3 SMEs: Their Capacity to Adopt Technologies

Studies on the diffusion of technology into Greek SMEs are not common; much of the existing literature comes from a variety of disciplines (management, marketing and information systems) and is somewhat disconnected from the economic influences on adoption.

[86] The OECD (2003) suggests that as much as 30 per cent of inventions generated in Greece (share of EPO patent applications) during the period 1996-1998, were owned by foreign residents.

Greek SMEs are burdened by the same constraints faced by SMEs elsewhere; namely the inability to get access to financial capital and the fact that they have to pay relatively high premiums in operations due to the absence of economies of scale. Bartzokas' (2001) work on Greek SMEs and their technology decisions identifies the presence of additional, country-specific barriers.

Bartzokas (2001) acknowledges that the difficulties in obtaining financial capital have a negative effect on the technology adoption decisions of SMEs in Greece. He argues that the problem is worsened due to the peculiarities of the Greek financial system. These are the existence of controls in the supply of bank credit (that is as distinct from interest rates) and the established culture of favouritism between old clients and state-controlled banks. Moreover, according to Bartzokas (2001), unrecorded turnover (a by-product of tax-evasion practices which are still widespread in SMEs) is also limiting their potential for external borrowing. Logotech's (2001b) extensive survey found that the high cost[87] of adoption and subsequent implementation prevented many firms from adopting.

The Greek SMEs ability to make adoption decisions is constrained by the poor education of their employees[88] and the consequent inefficiencies in terms of technological scanning. In Bartzokas' (2001) survey, participating small companies quoted trade fairs, independent suppliers and publications as their main *sources of information* about new technologies. Bartzokas (2001) points out that other local

[87] Since Greece is essentially a net importer of technological goods, the relative cost of adoption may be higher than that in technologically advanced countries due to local pricing policies.
[88] Liagouras, Protogerou and Caloghirou (2003) point out that SMEs in particular demonstrate an aversion towards highly skilled labour.

firms, technological institutions (Universities or PRI) and business associations were the least quoted sources. In fact institutional co-operation as a source of information was almost totally lacking for very small companies (Bartzokas, 2001). Such a dramatic absence of synergies puts into doubt the effectiveness of the Greek innovation system.

Surveys by Logotech (2001b), Bartzokas (2001), and Liagouras, Zambarloukos and Constantelou (2004) reveal that the lack of responsiveness of customers to new products is a significant barrier. A small firm's decision to invest in new technologies, regardless of whether they are product technologies or processes, is negatively affected by the absence of substantial demand by customers (Bartzokas, 2001). Logotech (2001b) also cites the lack of qualified personnel and the inability of many SMEs to conform by established regulations and standards as serious impediments. Finally, Bartzokas (2001) concludes that perhaps the most important inhibitor is the defensive business strategy prevalent in most SMEs in Greece. Technology adoption and any innovative activity are motivated as a response to a perceived threat rather than the opportunity of market creation or efficiency.

Since no definite diffusion measures exist, one can harness their ability to adopt technology by means of comparison. At the national level, a meaningful comparison can be made with firms of larger size. Eurostat (2004b) provides data on firms' acquisition of machinery (product technologies) and other external knowledge (process technologies) according to firm size. In the year 2000 (Table 4.7), most Greek firms engaged in acquiring machinery and other technological equipment while less than a fifth acquired other, intangible technologies. Table 4.7 confirms the overall aversion Greek firms have towards process technologies. This aversion is even more pronounced in small firms.

Table 4.7 - Greek SMEs: Proportion Engaged in Adoption Expenditure, 2000 (%)

	Small	Medium	Large
Acquisition of machinery and equipment	78	77	82
Acquisition of other external knowledge	16	18	22

Source: Eurostat (2004b)

A market survey for the penetration of the internet into Greek firms (Electronic Business Forum, 2004) found that less than one in five Greek firms had internet access in 2003 (Table 4.8). While diffusion levels of the technology have, overall, consistently increased, in 2003 firms with less than five employees had a diffusion level of 17 per cent, while the same level for firms with 6-10 employees was 52 per cent and 92 per cent for firms with more than 11 employees. The non-adoption of the internet by smaller firms emphasises the importance of firm size.

Table 4.8 - Firms with Internet Access (estimate)

Firm Size	*Population Total*	*2001*	*2002*	*2003*
1-5	488,158	66,304	88,714	83,948
6-10	10,738	3,927	4,012	5,668
>11	10,941	6,972	8,174	9,255
Total	509,837	77,203	100,900	98,871

Source: Electronic Business Forum (2004:17)

According to Hofstede (1985), Greek culture favours economic prudence and modesty rather than risk taking and uncertainty. Indeed, in Hofstede's study Greece ranks very high in terms of uncertainty avoidance[89]. Therefore, one may expect that Greek entrepreneurs would be apprehensive about the transfer of new technology. This would be particularly true of SMEs which have limited access to capital and favour long term survival over business expansion. This could partly explain why, in terms of when they adopt, SMEs in Greece are hardly ever among 'innovators' or even 'early adopters'. For innovation to occur in such an environment the technology's relative advantage must have been proved beyond reasonable doubt and the financial risk from its adoption be very small. Simultaneously, adoption of a technology hinges on the availability of financial capital and very specific market benefits coinciding. Hence, Greek SMEs could also be described as 'opportunity adopters', with their adoption decision being highly susceptible to policy incentives and other momentary environmental stimuli. For example changes in interest rates could make financial capital more affordable.

Table 4.7 confirms that Greek SMEs are essentially 'product adopters'; the majority of their adoption decisions involves product technologies, yet it is process technologies that offer the greatest opportunities for productivity gains. Greek SMEs rely heavily on (very cheap or unpaid) family labour. They are also most likely to employ low skilled immigrant workers (drawn by their cost-effectiveness and flexibility) particularly as SME labour needs are often casual or seasonal. The

[89] Geert Hofstede (1985) performed a categorisation of national cultures with relation to organisational structure and management attitudes. Hofstede questioned 116,000 IBM employees in different countries about their perceptions and preferences in terms of management style and work environment.

availability of low cost labour certainly has an impact on their perception of the usefulness of an organisational technology.

Finally, the ability of Greek SMEs to adopt technologies is held back by their long, technologically static, history. Their aversion towards innovative ideas is not something new; traditional work practices and tools have changed little over the decades. It follows, that their habitual indifference towards technological change is actually a barrier in itself. Their lack of adoption experiences means that they have hardly harnessed the positive qualities of innovations. Therefore, even if they are aware of the purpose of a technology, they are less likely to have an objective perception of the technology's relative advantage and its relation to their operational context. Importantly, their lack of assimilation experience means that they are not in a position to anticipate problems. Their position is exacerbated by ignorance about the supporting framework of technology adoption (the need for training, adjustments and continuous support by the technology's supplier, any network effects) as well as the absence of learning-by-doing with regards to the technology's operations. In such cases, SMEs in traditional industries are likely to experience diminishing returns from the adoption of technological goods; as problems occur in the intra-firm diffusion stage they find themselves unprepared for creative adjustments.

4.4.4 SMEs: Their Capacity to Innovate

Having observed economy-wide R&D statistics for Greece in §4.3.1 and in particular the lack of participation by private firms in general one would expect most Greek SMEs to have no participation in any kind of innovative activity. Indeed, Greek SMEs are overwhelmingly reluctant to invest and/or adjust their structures to encourage innovation. Greek SMEs compare unfavourably in terms of innovation output both nationally (compared with larger firms) and internationally. Eurostat's (2004b) Third Community Innovation Survey entitled "*Innovation in Europe 1998-2001*", provides detailed cross-industry information about the engagement of private enterprises in innovation. Eurostat (2004b) defines '*innovative activity*' as both R&D inventions and the adjustment and re-marketing of existing innovations – albeit one that goes further than their simple adoption or reselling. It is obvious from Table 4.9 that fewer Greek SMEs (28% on average) were engaged in innovative activity in the period 1998-2000 than in any other country in the EU (EU15). Small firms in particular (firms with 50 employees or less) had the lowest proportion at 26 per cent.

Table 4.9 - Proportion of enterprises with innovation activity, 1998-2000 (%)

	Total	Industry	Services	Small	Medium-sized	Large
EU15	**44**	**47**	**40**	**39**	**60**	77
Belgium	50	59	42	45	64	76
Denmark	44	52	37	40	54	67
Germany	61	66	57	55	72	86
Greece	*28*	*27*	*33*	*26*	*32*	*45*
Spain	33	37	25	30	45	67
France	41	46	34	31	52	76
Ireland	65	75	52	*	*	*
Italy	36	40	25	33	56	71
Luxembourg	48	49	48	42	59	95
Netherlands	45	55	38	39	59	79
Austria	49	53	45	42	65	89
Portugal	46	45	50	40	67	76
Finland	45	49	40	40	54	74
Sweden	47	47	46	42	60	72
United Kingdom	36	39	33	32	47	57
Iceland	55	54	56	51	70	79
Norway	36	39	34	33	45	64

** Data not available*

Source: Eurostat, (2004b)

In contrast with most of its European Union partners, the Greek economy never experienced profound industrialisation. Mechanisation in production has been sporadic and is only common in Greece's small manufacturing industry. This lack of economic transformation meant that small firms in traditional industries (agriculture, retail, handicrafts, light manufacturing and construction) came to dominate the SME landscape. Innovation-intensive industries were quickly dominated by larger firms. The profile of the average SME manager/proprietor also contributes to their low innovative capacity. According to Souitaris (2001), the average SME manager/proprietor in Greece is middle-aged and lacks recognised educational and professional qualifications. For many such individuals, founding a small business was one of very few possible professional outcomes. The professional body of knowledge they depend on for the running of their business is partly tacit craftsmanship passed on by the greater family and/or community and partly personal experience. Thus SMEs concentrated in traditional sectors, are motivated first and foremost by knowledge of a particular handicraft or trade and secondly by market imperfections.

Despite the fact that the traditional industries Greek SMEs operate in are generally characterised by low concentration, competing for ever greater market shares is low on their agenda. Family ownership has a direct effect on the competitive dynamism of such companies resulting in a strategy focused on survival. Innovation is an activity entailing risk; an activity which SMEs rarely engage in. Incremental edge technologies could only be researched and developed in an SME when the foreseeable benefits are undisputed and the scope of the innovation is as narrow as the particular SME's operating field. This is because innovations which are too generic and have broad applicability are usually developed first by larger firms. Therefore, realistically, SMEs could only innovate by tweaking and adjusting existing technologies to the needs of their niches.

There are also other reasons why the creation of new markets and the further entrenching of current ones as promised by innovation do not appeal to them. Many of them operate in markets which are very narrow to begin with (e.g. industrial plastics, pottery products, organic foods, other processed foods, localised tourist services etc) where they have managed to establish themselves by narrowing the potential market down even further and offering specialised products and services to specific niche segments. They may sometimes find themselves in a situation that could hardly benefit from innovation; indeed where 'traditionalism' is one of the product characteristics and one of the firm's marketing assets, one may argue that innovation could be harmful. Besides, the vast majority of SMEs in Greece appeal to a geographically constrained market. The spatial fragmentation of economic life in Greece due to the country's characteristic geomorphology and its abundance in physical barriers means that most SMEs target their services to their immediate locality. They view their potential clientele as saturated anywhere but where they are and, with the possible exceptions of ICT and transport technologies, see little reason for coming up with an innovation with anything but marginal market benefits.

Their capacity to innovate is further limited by the fact that very few of them operate in what could be described as a 'network industry'. As described earlier, firms in network industries have been found to be more likely to generate product or process innovations (Shy, 1996). Secondary evidence also indicate that private investment in R&D accounts for less than 20 per cent of the total GERD (Kastelli and Tsakanikas, 2000) and very few small firms have any part in it. As consequence, the domestic generation of novel ideas that could transfer into marketable products or services suffers and this is particularly apparent in the case of SMEs. Furthermore, even those SMEs in Greece that do innovate, do so without any influence from competitors or cooperation with customers and suppliers. While in 1998-2000 28 per cent of Greek SMEs generated innovation, a much smaller percentage did so as the result of combined efforts with other firms. Larger firms, especially in the services sector, readily show themselves willing to participate in cooperative activity resulting in innovation (Table 4.10). At the same time only a fifth of innovative smaller firms generated an innovation as the result of an inter-firm linkage.

Table 4.10 – Innovation Cooperation* Among Innovative Firms in Greece, 1998-2000, (%)

Number of Employees	*All Firms*	**Small**	**Medium**	**Large**
All Firms	**24**	22.2	24.5	48.7
Total industry (excluding construction)	**19.8**	17.8	20.9	44.6
Services (excluding public administration)	**39.6**	38	39.6	67.4

**defined as cooperation with both national and multinational firms resulting in 'innovation activity'*

Source: Eurostat, NewCronos website (theme9/innovat/inn_cis3)

Apart from resulting in greater efficiency (due to avoiding duplication of efforts, knowledge sharing) in R&D activities, cooperation should be highly valued as an end in itself. Greater networking with firms both horizontally and vertically helps in the development of innovations that are in touch with the company's real field of operations. Cooperation with a supplier may for instance result in an innovation promising the streamlining of the supply chain. At the same time, cooperation warrants that R&D products are just as appropriate for the company's internal operations as they are for its interactions with third actors.

Table 4.11 - Greece: Proportion of SMEs with Specified Innovation Expenditure, 2000 (%)

	Small	Medium	Large
Internally Commissioned R&D	53	61	79
Externally Commissioned R&D	13	23	31
Training	49	61	75
Market Introduction of Innovations	43	45	55
Other (design, preparation for production, deliveries)	39	45	41

Source: Eurostat (2004b)

The Ministry of Development performed a *National Innovation Survey in Greek Enterprises* (Logotech, 2001b) which is purported to adhere by Eurostat's innovation survey methodology and can thus give a further insight into the sectoral and systemic innovation competencies of Greek SMEs. The survey reveals that service sector firms engage in comparatively more innovative activity. It singles out the plastics industry, the basic metals and the machinery and equipment industries as the most innovative for the period 1997-1998. Therefore, innovation in Greek firms is heavily sector-dependent.

To conclude the analysis of diffusion factors in Greek firms in general and in SMEs in particular, Table 4.12 presents a synopsis of them as identified in the previous paragraphs. A general conclusion would be that while the environment in Greece in general appears to be progressively becoming more open and permissive of innovation diffusion, SMEs are currently not in a position to take advantage of such positive change.

Table 4.12 – Greece: Summary of Technology Diffusion Facilitators and Obstacles

Country Wide	*SME Specific*
low interest rates	low skilled labour
increased involvement of MNEs	aversion towards process/organisational technologies
highly skilled labour force	limited sources of financial capital
inefficient banking system	risk averse behaviour
higher technology costs	limited information sources
numerous government schemes	lack of co-operative/systemic behaviour

4.5 Conclusion

Chapter 4 presented an overview of the current state of affairs in the Greek economy, the historical development of Greek technology policy and drew a conceptual map of its transfer, diffusion and innovation competencies. The author highlighted the disappointing technological performance of Greek firms and described past official policy responses. The characteristics of Greek SMEs in particular were also investigated. This technology-diffusion centred exploration of the Greek economy is an original contribution by itself. In addition, an assessment of the overall economic environment is important as it forms the basis for the empirical part. It is also useful for the interpretation of findings and the provision of realisable policy suggestions.

Chapter 5 - Empirical Analysis of Technology Diffusion in Greek SMEs: The Case of Computers

It would appear that we have reached the limits of what it is possible to achieve with computer technology, although one should be careful with such statements, as they tend to sound pretty silly in 5 years.

John Von Neumann, 1949

5.1 Introduction

In the present chapter the author describes the model selected for primary research. Its characteristics and the selection of its variables are reviewed. Importantly, a set of propositions (hypotheses) to be tested by the model are set. In addition, the relative data set is devised and the target sample for data collection is set, with the potential adopters clearly defined. The model builds upon the academic work of a number of economists (Mansfield, 1968; Stoneman, 1995; Korres, 1997; Gourlay, 1998) by using factors the importance of which has been demonstrated in their empirical research. One of its aims is to test their validity in the context of SMEs in an economy in transition. The author builds upon a considerable volume of work by adopting many of the findings of established research projects and adapting them in such a way so as to reflect the particular characteristics of the Greek economy. Finally, the empirical investigation tests, for the first time, the importance of previous experiences and the technology's life expectancy as determinants of diffusion.

5.2 Rationale; Propositions of Empirical Study

The empirical study focuses on Greek small and medium enterprises (SMEs). The author has chosen to study the diffusion path of a selected technology over time and investigate the contribution of a set of independent variables on the decision to adopt. It is important to state at this stage that the primary unit of analysis is the individual *decision maker* (in this case the SME manager). This of course happens within a given context, which may also give an insight in the workings of the firm, the industry it operates in and finally the technology itself. The technology in question is microcomputers and more specifically their incarnation into a marketable product in the form of modern internet-enabled personal computers (IEPCs).

The selection of the technology (IEPC) is a reflection of its importance in the modern business world. Non-pervasive communication forms such as e-commerce applications[90], new customer and business communication channels[91] and access to vast pools of knowledge are only part of the benefits that the adoption of modern internet-enabled computers can provide to companies. The benefits of the technology are not limited to its networking abilities; Matarazzo and Connolly (1999) argue that modern IT infrastructure forms the backbone of a successful organisation and effective intranets have proved crucial factors in firm growth.

The case of Greece is of particular interest as it is a country that has escaped the vicious circle of underdevelopment while still sharing many of the characteristics of less developed countries[92]. Therefore findings from such a study could have a broad appeal for other countries in Southern Europe which share similarities in economic structure and socio-political culture (e.g. Spain and Portugal). Greece's experience with technological dissemination while adopting its structures to European Union standards may also provide a useful record of past experience for new EU entrants.

[90] Networked personal computers have greatly enhanced the ability of firms to perform transactions. This has been possible through such application systems as EPOS (Electronic Point Of Sale – what happens when one uses a credit card), EFT (Electronic Funds Transfer), EDI (Electronic Data Interchange, i.e. business to business knowledge sharing and communication), EBPP (Electronic Bill Presentment and Payment) etc. It is widely accepted that the integration of such applications with accounting software have increased efficiencies in finance, logistics and overall administration and decision making.

[91] Through business to customer (b2c) e-commerce and business to business (b2b) e-commerce applications

[92] i.e. a disproportionately large primary sector, widespread corruption and an overstretched and riddled with bureaucracy state apparatus

The previous chapter analysed the technological 'capital' of Greece and highlighted some major inadequacies particularly with regards to innovative activities among small private firms.

Greece has been slow to catch up with its European Union partners in terms of access to the Internet. Studies commissioned by the Ministry of Development (Logotech, 2001b) and the Ministries of Economy and Finance and the Interior (Electronic Business Forum, 2003) have concluded that Greek SMEs fail to reap the benefits of modern technology; not only are they unable to engage in innovative activities, they are also too slow to take up existing technologies. Data provided by ICANN[93] (2003) and ESIS[94] (2000) suggest that take up and usage of the Internet in Greece is among the lowest in Europe despite numerous efforts by the government's "Greece in the Information Society" initiative. More specifically by 1999 only 32 per cent of Greek firms had access to the Internet (compared to a 50 per cent EU15 average), though annual Internet adoption growth was slightly higher than the EU average (27 per cent) at 28 per cent (ESIS, 2000). The impetus for catch-up is great since, as shown by Daveri (2002), Greece stands to gain significantly in terms of productivity from ICT adoption.

The goals of the empirical part are multiple; first of all, collecting data on the diffusion of internet-enabled computers within a representative sample of the Greek SME population and testing them against some widely accepted determinants of

[93] The Internet Corporation for Assigned Names and Numbers (ICANN) is a technical coordination body for the Internet.
[94] ESIS stands for "European Survey of Information Society Projects and Actions"

technological adoption should help corroborate the results of earlier studies on the significance of each determinant. Moreover, the importance of factors specific to this environment is to be established. This should contribute towards determining the validity of a number of hypotheses, set out in §5.3.4.

It is hoped that the results of the analysis of this data could prove useful in helping policy makers and firm managers decide how to encourage the diffusion of similar technologies to industry.

5.3 Case Study: The adoption of IEPCs by SMEs in Greece 1990-2002

5.3.1 Selection of Technology

The technology selected for the empirical part of the project could be generally described as "a personal computer with access to the internet", or an internet-enabled personal computer (IEPC). For the purposes of the empirical investigation, the selection of the end-product the technology translates into (IEPC) has been preferred over the generic technology itself (the Internet).

Personal computers or PCs have been available to most firms in Greece for almost the past three decades. The operational benefits they bring to firms have had a profound impact on the economy and contributed to what Castells (1996) calls an '*information society*'. At the first stage of their market entry (1970-1989), personal computers' primary role was that of an information archival and retrieval machine; database applications enabled firms to improve efficiency dramatically in their accounting, knowledge base and inventory operations. Other uses for computers at the time, such as generalised manufacturing automation were only relevant to mechanised industry (a relatively small sector in Greece) and typically appealed to larger corporations. Stoneman (1976) conducted research in the diffusion of computers in the United States at the time and concluded that acquisition cost had been a major factor in this first stage of personal computer diffusion. It is therefore no surprise that in an economy where firms have traditionally being faced with restricted access to finance[95], few firms could justify the considerable cost of acquiring equipment and adjusting their firm structures (employee training, organisational restructuring). Added to this, one could presume that even those firms which did make the bold step and adopted early microcomputers are likely to have had an overall negative experience. This is because the adoption occurred in the context of a non-conducive environment[96] where the utility of what was then an immature technology may not have been high. That is not to say that a successful adoption would have been impossible; indeed such a success may predispose adoption of later generations of the technology.

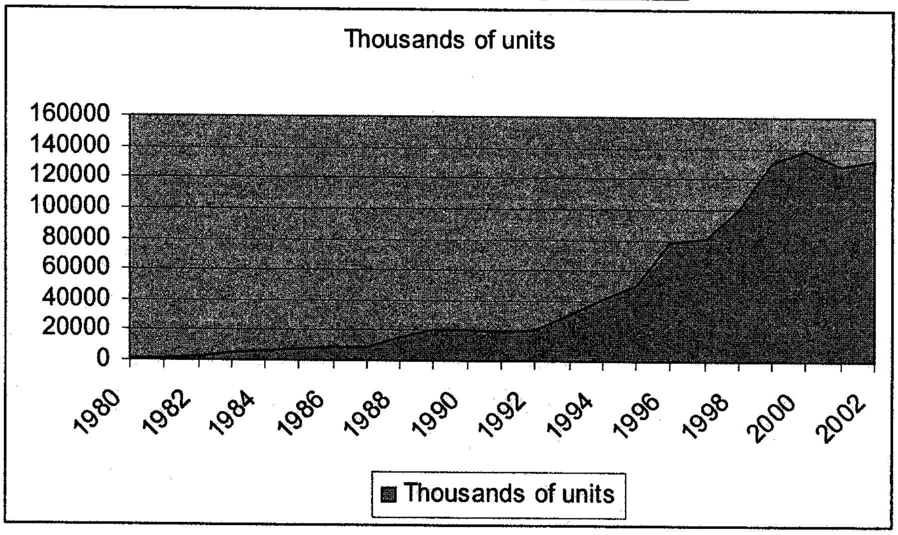
The features and uses of microcomputers evolved progressively at an unprecedented rate. However, their appeal to the broad market proved somewhat inelastic to the rate of technological progress. It was only after the marketable feasibility of the global

[95] During the period under analysis (1970-1989), Greek firms seeking finance had to deal with soaring interest rates (averaging 18 per cent) and disproportionately high taxation (in relation to their ability - particularly SMEs).

[96] During the period in question (1970-1989), Greece possessed a rudimentary telecommunications infrastructure and was characterised by the absence of appropriate technology training and education. Added to that a corporate (as well as popular) culture favouring 'conservation' over innovation make it unlikely that where adopted the technology would have been used effectively.

computer network known today simply as 'the internet' that computers infiltrated every aspect of our lives. In IT terms the internet is often thought of as a *"killer application"* – a term used to denote a technology the usefulness (and consequently the market potential) of which is immense. IEPCs are thought of as the greatest killer application the IT industry has ever come up with - a fact which contributed to the selection of the technology. Their emergence in the early 1990s[97] signifies a starkly distinct second stage in the diffusion of microcomputers and merits distinct analysis (Figure 5.1).

Figure 5.1 – Global Computer Sales



Source: International Data Corp. (2003)

A study by Caselli and Coleman (2001) on the international diffusion of computers found that the limited availability of information with regards to the technology's relative advantage as well as its cost were the primary factors obstructing adoption. Indeed, this may be true but one could argue that it could be offset by government

[97] Although the Internet can trace its roots to research by the U.S. military in the early 1970s (ARPANET), it was the advent of the web and the first web-browser in 1993 (a now defunct piece of software known as 'Mosaic') that global communications over the TCP/IP protocol (the backbone of the internet) really took off.

intervention; the GSRT under the EU sponsored EPAN (2000-2006) framework has been actively pursuing to raise awareness and even part finance a range of IT related technologies. Such attempts directly relate with the government's vision of Greece in the 'information society'.

More specifically, the "Go-Online" scheme administered by EOMMEX (The Hellenic Organisation for Small, Medium and Handicraft Enterprises) aims to give a technological boost to the firms that appear to be most in need of it; Greek SMEs. The scheme is of particular interest to the present study since it part finances (up to 40 per cent) the purchase and installation of IEPCs for SMEs, thus directly affecting the determinants of cost, capital availability and relative advantage. The first part of the project ran in the period of January 2000 – December 2003, for which 50,000 funding places had been allocated. At the same time, EOMMEX embarked on an informational campaign of unprecedented scale aimed at promoting the scheme and the merits of technologies themselves[98], thus influencing the SMEs directors' perception of the IEPCs relative advantage. By December 2003, only 20,056 SMEs had applied and qualified for the scheme, less than 50 per cent of the original target. This appears to contradict relevant theory, which as demonstrated previously suggests that the technology's cost and the adopters' perception of its relative advantage are the most significant factors. Applying a customised model which monitors the significance of a wide array of determinant variables as suggested by theory and

[98] Go-Online's promotional campaign includes daily listings in the press and public airings on national television and radio – It is noteworthy that it has also resorted to the direct mailing of the members of the Athens Chamber of Commerce (EBEA).

demanded by the circumstances would contribute to the development of an explanation for this paradox.

5.3.2 Target Population and Sample Considerations

A representative sample of 100 companies has been chosen based on data on the make up of the Greek SME sector (data primarily from the National Statistics Service and EOMMEX). Companies contact details for Athens were obtained from the Athens Chamber of Commerce[99] and for the rest of Greece (particularly for the part involving questionnaire distribution via email) from the Greek government's Information Society Framework Initiative "Go-Online[100]" as well as from personal recommendations.

It would naturally be desirable for the sample to be representative of the whole population. The purpose of studying this particular sample has to do with understanding the qualities of the population as a whole. In other words, because it is realistically impossible to collect data on the whole population, information is acquired by means of inference; one may think of the sample as a small-scale version of the population. Its study allows one to infer that any findings that hold true of the sample, are also true for the population as a whole. Logically, inference is only possible when the sample is representative of the population. Nevertheless, the degree

[99] http://www.ebea.gr
[100] http://www.go-online.gr

of allowance for deviation from the population is dependent on the estimation method[101], as discussed in sample analysis (§6.3).

As mentioned previously, the total population of Greek SMEs numbers 509,837 firms (National Statistics Service, 1995). These firms are bound to differ from each other in so many aspects that a perfectly representative sample would be extremely difficult if not impossible to compile. During questionnaire distribution the author continuously monitored the results obtained and targeted those firms that would ensure that the data collected were kept close to the intended sample. Given the limitations of the present survey, a conscious choice was made for the sample to be representative only against what were judged to be the most important aspects. Therefore the author concluded that a suitable sample should ensure a proportional representation of firms in the following dimensions;

- *Composition of Greek SMEs with regards to industrial sector.*

The vast majority of Greek SMEs are to be found in the retail industry, closely followed by firms in real estate, financial intermediation and light manufacturing. Past studies have singled out sectors such as manufacturing as more innovative and more likely to adopt widely applicable technologies. Firms operating in so-called network industries (IT, communications, banking and finance) have also been found to be among innovators. Conversely, firms in the primary sector and in other traditional industries (e.g. handicrafts) are usually expected to be among technological laggards.

[101] For example, proportional representation is less important in non-linear models. Enough observations of the explanatory characteristics are all that is needed rather than a comprehensively representative sample.

- *Composition of Greek SMEs with regards to size.*

Firm size is one of the undisputed determinants of adoption. There is strong evidence in literature to suggest that larger firms tend to be among the earliest adopters. A representative sample with regards to size could help towards alleviating sample bias. This is because the size of a firm can act as a proxy for a range of other characteristics. All but very few Greek SMEs are very small, usually employing less than 10 employees (microfirms). The challenge here is to actually encounter enough SMEs that are larger than a microfirm in order to enable one to make meaningful comparisons.

- *An attempt was also made to create a sample that is representative with regards to geography.*

Finally, geography was taken into consideration, particularly as there is great economic disparity between urban and rural areas. With an overwhelmingly large proportion of the population of Greece living in the capital Athens[102] the bulk of economic activity is also concentrated there. Data collection ensured that a similar proportion of respondents was based in Athens versus the periphery.

5.3.3 Selection of Variables

Traditional diffusion theory has pointed at a number of variables that may be significant in a given context. Setting the context and deciding on the relevance of previously identified variables is an important part of empirical research preparation; it serves to underpin the theory behind each independent variable and link the present work with other contributions in the field. The variables in question have been

[102] A proportion that currently stands close to 50 per cent.

mentioned in the literature review in Chapter 3 and are summarised in Table 3.1. The following table (Table 5.1) outlines which of the variables identified in literature are to be empirically tested and why. Due to contextual factors not all traditional determinants of diffusion are of importance in the present study. Under the 'Rationale' heading, the deductive reasoning for the selection or non-selection of a traditional variable is explained. Finally, a final verdict on whether they should be tested empirically is provided.

Table 5.1 Selection of Variables

Variable Identified in Literature	**Indicative Literature References**	**Rationale**	**Verdict**
firm size	Mansfield (1961); Ethier and Markusen (1991); Geroski (1999); Bartoloni and Baussola (2001); Hollenstein (2001)	Although the focus of study is SMEs, there are significant size variations among them which may account for different adoption experiences. The predominance of the micro-firm (<10 employees) in the Greek SME sector may prove crucial.	*significance to be tested*
firm's management structure	Mansfield (1964); Romeo (1975); Souitaris (2001); Fisher-Vanden (2003)	By definition small firms have little room for developing a management structure. Typically, most (if not all) decision making authority is concentrated in the owner of the firm (Julien, 1998). Greek SMEs in particular, being family centred, have relatively uniform management structures (Kyriakoulias and Soumeli, 1999). Fisher-Vanden (2003) also argues that management structure is more relevant to intra-firm diffusion.	*not relevant*
firm's rate of growth	Gourlay (1998); Lyberaki and Mylonas (2000)	SMEs in booming sectors engage heavily on investment and are thus more likely to adopt a technology. Large capital inflows from the EU's Third Community Support Framework and government spending ahead of the Olympics have fuelled rapid growth in SMEs, particularly in the construction industry.	*significance to be tested*

perceived industry concentration	Nasbeth and Ray (1974); Romeo (1975); Karshenas and Stoneman (1995); Goel and Rich (1997); Pack (1999)	Firms that find themselves under pressure from competitors, theory suggests, are more likely to adopt. Strategic considerations (Karshenas and Stoneman, 1995) may also prevent them from adopting until most other firms have done so. Recent years have seen the liberalisation of the Greek economy, its exposure to global market forces and consequently lower levels of market concentration.	*significance to be tested*
perceived availability of financial capital	Rogers (1983); Cobham (1999); Caselli and Coleman (2001)	SMEs have difficulties obtaining the means to finance the considerable investment cost involved in the adoption of a technology (both purchase and adjustment). This is also true of SMEs in Greece which until recently had to deal with a volatile macroeconomic environment and a heavily regulated financial system.	*significance to be tested*
linkages with multinational enterprises	Blomström and Persson (1983); Antonelli (1985); Haddad and Harrison (1993); Blomström and Sjoholm (1998); Lorentzen and Mollgaard (2000)	It has been shown empirically that MNEs are not only major innovators but also facilitators of technological diffusion. It is therefore logical to assume that SMEs which deal with MNEs regularly are more likely to adopt a technology.	*significance to be tested*
technology's perceived relative advantage	Rogers (1983); Davis (1989); Gourlay (1998); Caselli and Coleman (2001); Hollenstein (2001); Carter and Belanger(2003)	Countless studies have shown this to be an important demand-side determinant of diffusion regardless of the context. High perceived relative advantage indicates that a need (demand) is present for the technology to fulfil. Whereas a high relative advantage is by no means guarantee that a firm will adopt a technology early, a low perception of the factor is almost certainly a guarantor of non-adoption (no demand, no transaction).	*significance to be tested*

technology's relative advantage in comparison with substitutes	Stoneman (1983)	Technologies are essentially products. When alternative technologies are available which are fit for the same purpose they may often compete for the market's attention. In the case of IEPCs, there are no real substitutes[103] and as a result the choice is one of adoption or non adoption.	*not relevant*
technology's perceived cost in relation to a company's ability	Solo (1966); Rogers (1983); Gourlay (1998)	The adoption of a technology that is considered useful but is not directly related to the firm's operational core may be more sensitive to cost considerations. Closely linked with the availability of financial capital, perceived cost is another demand-side factor that may prohibit adoption for firms of modest means.	*significance to be tested*
technology's trialability	Rogers (1983)	Getting the opportunity to try a technology prior to making a decision on adoption is likely to affect a firm's perceived relative advantage. In the case of IEPCs and their applications trying the technology is possible. Cases where a technology's trialability contributed to the decision to adopt could also indicate strong inter-firm linkages.	*significance to be tested*
technology's perceived complexity	Rogers (1983); Davis (1989)	The perceived complexity of a technology may be an inhibitor to adoption. A complex technology may take significant lengths of time to become implemented and yield the expected benefits – time that firms translate into lost work-hours, confusion and other inefficiencies.	*significance to be tested*
technology's observability	Rogers (1983)	Observability is termed as the extent to which the benefits stemming from the use of an innovation are visible to others (Rogers, 1983). Innovations that have observable benefits are adopted more quickly. Extensive advertising, media	*significance to be tested*

[103] Though there exist a host of 'information appliances' (set-top boxes, information kiosks, mobile phones, personal digital assistants etc.) that promise access to the internet, personal computers are by far the most common medium used to do so.

		publicity and the nature of the technology itself[104] can all affect a technology's observability. The benefits of IEPCs have been advertised extensively. The high observability of a technology in a business environment may also imply inter-firm relationships.	
technology's network effects	Shy (2001); Inceoglu and Park (2004)	The diffusion of ICT technologies has been found in several cases to be influenced by network effects; that is the benefit from the use of a technology increases in the presence of complementary technologies. In the context of the present study however any network effects would be small as very few Greek SMEs have invested in any other form of ICT technology (Ministry of Development, 2001). At the same time, quantifying those network effects would pose a very real methodological problem.	*not relevant*
technology and firm are perceived as compatible	Rogers (1983); Carter and Belanger(2003)	A technology may posses characteristics that may deem it 'incompatible' with a firm's operational and organisational competences or existing technological infrastructure.	*significance to be tested*
previous experiences	(newly introduced variable) related to *learning effects* as mentioned by: Colombo and Mosconi (1995); Hollenstein (2001)	All decisions are to an extent based on experience; learning occurs through a process of trial and error. An earlier adoption of a vintage technology may predispose the decision to adopt a technology with similar characteristics. They key measure is its success. The author proposes that firms that adopted an earlier 'generation' of the technology in the period 1970-1989 and judged its implementation to be 'successful' may be more likely to adopt IEPCs.	*significance to be tested*

[104] E.g. A technology that is used outdoors is bound to be seen by a greater number of potential adopters; it would therefore have a higher observability, than for instance, one that is only used indoors.

technology's perceived life expectancy	(newly introduced variable) related to *expectations* as mentioned by: Rosenberg (1976); Doraszelski (2004)	Innovation in ICT technologies is so intense that old technologies are superseded by new ones at an unparalleled rate. IEPCs have a limited life-span. It is the author's assumption that decision makers are aware of this. They make a calculated decision on adoption based on their perception of the technology's life expectancy. As the life expectancy of IEPCs is generally small, firms that take the factor into account in their decision to adopt may postpone adoption. This is because potential adopters see the technology as 'immature'; they postpone the decision to adopt until the technology has reached maturity.	*significance to be tested*

5.3.4 Formulation of Hypotheses

The outline of clear and concise hypotheses is an essential part of the empirical process. Hypothesis testing ensures clarity and consistency through the harmonisation of different terminology used in literature; it also aids in goal-setting and it helps ensure that any quantitative methods are only a means to an end rather than objectives in their own right. Its ultimate aim however is to add a certain degree of validity to logically viable propositions, given the constraints of relevant methods[105]. Following the (literature-backed) selection in §5.3.3 and bearing in mind the context of the survey (environment and technology selected), the author proposes a total of eighteen hypotheses.

[105] Constraints such as problems of causality and statistical inference.

To begin with, the size of the firm in question and the speed at which it grows have been found to be positively correlated with the decision to adopt (Gourlay, 1998; Geroski, 1999). Larger companies have also been found to adopt earlier than others. Hence;

> **H1**: *Larger firms are more likely to adopt*
>
> **H2**: *Larger firms are predominantly among the earliest adopters.*
>
> **H3**: *Firms that grow rapidly are more likely to adopt.*

Rogers (1983) argues that the adoption of a particular technology hinges largely on its perceived advantages over the technology currently in use. The magnitude of the firm manager's expectations for the technology could be so great as to render other determinants irrelevant. Hence the author proposes;

> **H4**: *The higher the perception of the technology's relative advantage the higher the chances of the technology being adopted.*

In addition, Caselli and Coleman (2001) cite the availability of financial capital as the primary determinant of ICT adoption. SMEs have difficulties obtaining the means to finance the considerable investment cost involved in the adoption of a technology (both purchase and adjustment). This is also true of SMEs in Greece which until recently had to deal with a volatile macroeconomic environment and a heavily regulated financial system. Even at present, IOBE (2004) points out that as much as

70 per cent of finance for small firms comes from 'atypical sources', such as finance obtained from family members. Hence;

> **H5:** *The availability of financial capital facilitates adoption while the lack of financial capital discourages it.*

MNEs are not only major innovators but also facilitators of technological diffusion Empirical studies have also demonstrated a strong association between diffusion and MNE linkages (Antonelli, 1985). It is therefore logical to assume that SMEs which deal with MNEs regularly are more likely to adopt a technology. Moreover, the nature of the co-operation may also be important as hinted by Blomström and Persson (1983). Lundvall (1992) emphasises that technical change can occur as the result of user-producer relationships. Hence the author devised the following five hypotheses;

> **H6**: *SMEs that engage in any co-operative relationship with multinational enterprises are more likely to adopt the technology while firms that do not co-operate with multinationals are less likely to adopt.*
>
> **H7**: *SMEs which are trading partners of multinational enterprises are more likely to adopt the technology.*
>
> **H8**: *SMEs which are suppliers of multinational enterprises are more likely to adopt the technology.*
>
> **H9**: *SMEs which engage in joint R&D efforts with multinational enterprises are more likely to adopt the technology.*

H10: *SMEs which engage in joint human resource development (HRD) activities with multinational enterprises are more likely to adopt the technology.*

All decisions are to an extent based on experience; learning occurs through a process of trial and error. An earlier adoption of a vintage technology may predispose the decision to adopt a technology with similar characteristics. They key measure is its success. The author proposes that firms that adopted an earlier 'generation' of the technology in the period 1970-1989 and deemed its implementation to be 'successful' may be more likely to adopt IEPCs. Specifically;

H11: *Firms that adopted an earlier generation of the technology and considered the experience as beneficial are more likely to adopt, whereas firms with no previous or negative previous experience of an earlier generation of the technology are less likely to adopt.*

The technology's perceived cost against the firm's ability has also been found to influence adoption patterns. Solo (1966) and Rogers (1983) argue that cost is an obstacle to adoption for firms of modest means. The factor is closely linked to the availability of financial capital, though it differs in one important respect; the reference to the 'firm's ability' gives information with regards to the company's own financial resources as opposed to both internal and external ones. Hence;

> **H12**: *The technology's perceived cost (in relation to the firm's ability) is negatively related to adoption.*

Firms that find themselves under pressure from competitors, theory suggests, are more likely to adopt (Davies, 1979). This theoretical assumption has been confirmed empirically by Goel and Rich (1997) in their study of the adoption and diffusion of commercial aircraft innovations. Strategic considerations (Karshenas and Stoneman, 1995) may also prevent them from adopting until most other firms have done so. Recent years have seen the liberalisation of the Greek economy, its increased exposure to global market forces and consequently increased the competitive threat to SMEs;

> **H13:** *Firms that perceive their industry as 'competitive' are more likely to adopt while firms that perceive little competition in their industry are less likely to adopt.*

Rogers (1983) considers apprehension about a technology's complexity to be a major factor inhibiting widespread adoption. IEPCs are a general purpose technology with so many applications that require continuous learning and adjustment. At the consumer level, Buhalis and Deimetzi (2003) consider the perceived complexity of information technology appliances as a major obstacle to their diffusion in Greece. Hence;

> **H14**: *Technologies which firms deem 'complex' are less likely to be adopted.*

Innovation in ICT technologies is so intense that old technologies are superseded by new ones at an unparalleled rate. IEPCs have a limited life-span. It is the author's assumption that decision makers are aware of this. They make a calculated decision on adoption based on their perception of the technology's life expectancy. As the life expectancy of IEPCs is generally small, firms that take the factor into account in their decision to adopt may postpone adoption. This is because potential adopters see the technology as 'immature'; they postpone the decision to adopt until the technology has reached maturity. Therefore;

H15: *Technologies with a low life expectancy are less likely to be adopted.*

Rogers (1983) argues that technologies that are more frequently observed in action than others have a better chance of diffusing. A technology with high observability 'advertises' its qualities and possibly influences adopters' perceptions of the technology's relative advantage. Therefore;

H16: *Firms whose members of staff observe the technology in action elsewhere are more likely to adopt.*

Rogers (1983) regards experiences with instances of the technology in their operational environment as a significant facilitator. Using the technology in its intended operational context alleviates fears about the technology's complexity and reassures potential adopters that the technology is appropriate. From this follows that;

H17: *Firms which have had the opportunity to test the technology are more likely to adopt.*

If a technology is to be used effectively it must be properly integrated into the company's operational structures. In the case of IEPCs there is a need for the technology to be compatible with the company's existing hardware as well as its operational habits. Perceived compatibility is more pervasive than simple hardware synergies; the presence of staff that is acquainted with the use of the technology would make it more 'compatible' in the view of the decision maker. So one can assume that:

H18: *Technologies which are perceived as 'compatible' are more likely to be adopted.*

These hypotheses are to be tested empirically using data collected by means of questionnaire in Greek SMEs (see §5.5). The hypotheses are to be accepted or rejected following econometric estimation and appropriate test statistics.

5.4 Measuring the Determinants of Adoption: The Model

The method of estimation is determined by the availability and nature of the data as well as the desired research outcomes. According to Karshenas and Stoneman (1995) traditionally, economists have used two generalised methods of estimation. The first method involves a two-stage procedure where the diffusion curve is fitted to the absolute or relative number of adopters in a number of industries and then linear regression is used to explain the slope coefficient of the fitted curves, thus in essence identifying the factors that affect the speed of diffusion. However, this method requires that aggregate time-series data (for twenty-five years or more) in a number of industries are available. This method is typically used to study the diffusion path of older technologies that have diffused widely, not confined to particular parts of the economy. Examples of applications of this method are studies on the diffusion of electricity (Rose and Joskow, 1990), the steam locomotive (Rosenberg, 1976) and higher yield corn seeds (Griliches, 1957). Indeed, this is the most established method of estimation and its reliability is widely acknowledged (Karshenas and Stoneman, 1995).

However, in the present case the diffusion of internet-enabled microcomputers in the Greek SME sector has been taking place for, at best, a decade (therefore rendering time-series analysis unreliable) and on top of this obtaining data on a sufficiently large economy-wide sample is a difficult task that is beyond the scope of the present project.

The second method used in economic literature is a single-stage estimation method involving making the parameters of the diffusion curve variable functions of economic variables. According to Karshenas and Stoneman (1995) this method can be used where one can assume the existence of perfect information and as such is popular with studies of newer, yet widely known technologies. This method also suits cases where one can assume that the probability of adoption and the diffusion parameters are non-linearly related[106].

In its commonest form this can take the form of a ranking econometric model designed to analyse qualitative data. In a ranking model the independent variables take the form of ranks[107], and as such are used to investigate relative quantitative trends rather than absolute sizes. Stoneman and Kwon (1994), Gourlay (1998), Lorentzen and Mollgaard (2000) have applied probit models to the diffusion of industrial processes, bank ATMs and car components respectively.

The rank (probit or logit) theories on technological diffusion assume that different firms adopt a technology at different times because of their inherent characteristics. Potential users of a new technology differ from each other in some important dimension such that some firms obtain a greater gross return from new technology than do others. Kauffmann (1998) and Karshenas and Stoneman (1995) argue that the logit model is the most appropriate model to use for new technologies. A logit model can be thought of as an alternate version of the probit model. Their primary difference lies with the fact that the logit model assumes a logistic probability distribution whereas a probit model assumes a normal distribution.

Indeed, Kaufmann (1998) applied the model on a study intended to forecast the diffusion path of a hypothetical advanced environmental technology. Goel and Rich

[106] i.e. A rise in the value of the determining parameters will not cause an analogous rise in the probability of adoption.

[107] e.g. FIRM SIZE=1 for small, 2 for medium, 3 for large in other words they are ranked according to a set convention of interval scales

(1997) used a logit model to explain the diffusion determinants of commercial aircraft technologies in US airline firms. The logit model has also been used before to map the diffusion path of manufacturing processes by Bartoloni and Bausola (2001) and internet banking by Courchance, Nickerson and Sullivan (2002).

A logit model has been chosen in the present case where the dependant variable (Y_i) is dichotomous (the decision to adopt) and the independent variables (determinants of diffusion) are subject to ranking. If one assumes that the factors determining a firm's decision to adopt or not are those stated in §5.3 then it should be possible to construct a logit model modelling the firms decision (Y_i). The selection of the logit model was not made at random;

(i) The fact that the logit model is qualitative (compatible with perceived respondents' values) and can accept data for dichotomous variables serves the purpose of the analysis of IEPC diffusion. A logit estimation allows for ranking (e.g. from 1 to 5) of the independent variables thus making it appropriate for the analysis of qualitative questionnaire data, especially since many of the variables are based on perceptions.

(ii) Just like the probit model examined earlier it is capable of using inherent firm characteristics as well as environmental variables to explain the timing of the decision to adopt.

(iii) The logit model's ease of use (through ML estimation for individual data) and the clarity of analysis it allows due to its relatively simple mathematical concepts make it even more appealing.

(iv) The logit model can utilise primary data from questionnaires for relatively short periods and is thus best suited to the survey of technologies that diffuse quickly and have limited life-span.

(v) Unlike the linear probability model (LPM) it constrains the predicted probabilities between 0 and 1.

(vi) It produces easily communicable odd ratios of the marginal effects of a single unit's increase in each independent variable on the probability of adoption.

Y_i, the decision of a firm i to adopt a technology, is a binary or dichotomous variable (Gujarati, 2002). Y_i (the dependent variable) is modelled against a set of (thirteen) independent explanatory variables ($\beta_2 X_{2i} + \beta_3 X_{3i} + \ldots \beta_{14} X_{14i}$) collectively referred to as X_i. Y_i can take the values of either **0** (indicating non-adoption of the technology[108]) or **1** (indicating adoption of the technology). Hence, the probability distribution function of a firm's decision to adopt will look like the following:

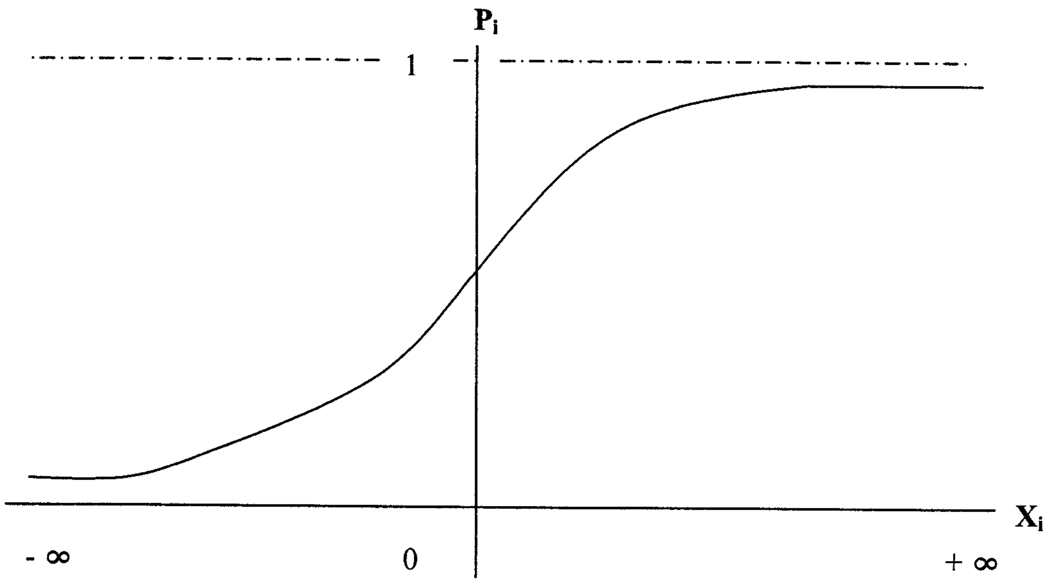
$$P_i = \frac{1}{1+e^{-Xi}} = \frac{e^{Xi}}{1+e^{Xi}} \quad \textbf{(5.1)}$$

According to Gujarati (2002) the distribution of probabilities as described in (5.1) represents what is known as the (cumulative) logistic distribution function (Figure 5.2). In other words as X_i increases, P_i increases as well but never stops outside the 0-1 interval and their relationship in non-linear. The assumption of non-linearity means that the probability of adoption approaches zero at a progressively slower pace as X_i gets small and approaches one at a progressively slower pace as X_i gets very large

[108] It is important to note that an instance of non-adoption at time t does not represent a final and irrevocable decision not to adopt but rather a ***deferment*** of the decision for a later time.

(Gujarati, 2002). It is important to point out that the logistic distribution function plotted in Figure 5.2 is merely notional and that the actual distribution is bound to vary significantly as its non-linearity is affected by the values of the regressands – though it is most likely it will broadly conform to the s-shaped convention.

Figure 5.2 – The Logistic Distribution Function



One can now consider the following regression model:

$$Y_i = \beta_1 + \beta_2 X_{2i} + \beta_3 X_{3i} + \ldots \beta_{14} X_{14i} + u_i \quad \textbf{(5.2)}$$

It is assumed that for each firm *i* the decision to adopt (Y_i) is dependent on the values of the regressors X_{2i}, X_{3i}, X_{4i}...until X_{14i}, plus a disturbance term u_i. The independent variables are defined as described in Table 5.2.

Table 5.2 – Theoretical Outline of Independent Variables

Firm Characteristics:

X_{2i} (*fsize*)	FIRM SIZE: The size of a firm is thought to be an important variable as it affects directly the availability of finance for research and technology adoption and indirectly the company's ability for technological scanning. Can take values 1-5.
X_{3i} (*fgrowth*)	RATE OF GROWTH: Fast growing firms have been previously shown to be firms that also adopt technology early. Firms that grow quickly are generally firms with better access to capital funds and from a cultural viewpoint are seen as risk-takers. Can take values 0 (little or no growth), 1 (substantial growth).
X_{4i} (*prevxp*)	PREVIOUS EXPERIENCES: Successful previous implementations of a similar technology are expected to positively predispose the adoption of a modern technology. Similarly negative or no experience may have an adverse effect on the decision to adopt. Can take values 0-1.
X_{5i} (*cost*)	COST OF ADOPTION RELATIVE TO ABILITY: Different firms have varying ability to finance the adoption of a technology. A perceived variable, it tests how heavy the burden of investment is perceived to be at the time of adoption. Can take values 1-5.

Industry Characteristics:

X_{6i} (*conctr*)	PERCEIVED CONCENTRATION: Level of competition faced by firms at the time of adoption as perceived by the questionnaire respondents. Can take values 1-5.
X_{7i} (*mnelnk*)	LINKAGES WITH MNEs: Firms that cooperate with multinational companies as either trading partners or suppliers or in terms of R&D and HRD are expected to adopt the technology. Can take values 1 (no linkages), 2 (trading partner), 3 (supplier), 4 (R&D cooperation) and 5 (HRD cooperation).
X_{8i} (*capavail*)	PERCEIVED AVAILABILITY OF FINANCIAL CAPITAL: Since the adoption of the technology is not costless, it is only realisable when financial capital is available. Therefore, if capital is perceived as being easily available the likelihood of adoption becomes greater. Can take values 1-5.

Technology Characteristics:

X_{9i} (*reladv*)	PERCEIVED RELATIVE ADVANTAGE: The perception that adopters have about the positive utility they expect to enjoy from adoption versus the costs involved. This may translate in increased profitability, productivity gains or cost-saving and is offset against purchase and running costs. Can take values 1-5.
X_{10i} (*lifexp*)	PERCEIVED LIFE EXPECTANCY: It is logical to assume that technologies which are expected to be replaced shortly will have trouble diffusing. The variable denotes whether the technology's life expectancy was an important consideration at the time of adoption. Can take values 0 (not important), 1 (important).
X_{11i} (*complx*)	PERCEIVED COMPLEXITY: The degree of a technology's complexity may frustrate potential adopters. Technologies with low perceived complexity are more likely to adopt and vice versa. Can take values 1-5.
X_{12i} (*compbl*)	PERCEIVED COMPATIBILITY: If a technology is to be adopted it is important that it is compatible with the firm's existing organisational structures and technological hardware. Can take values 1-5.
X_{13i} (*trial*)	TRIALABILITY: Previous research has indicated that in cases where adopters had the chance to try the technology, adoption was much more frequent. Can take values 0 (technology not tried), 1 (technology tried).
X_{14i} (*obsrv*)	OBSERVABILITY: Previous research has indicated that in cases where adopters had observed the technology in action , adoption was much more frequent. Can take values 0 (technology not observed), 1 (technology observed).

Because the model will analyse data on individual adopters, Gujarati (2002) argues that the usage of Ordinary Least Squares (OLS) would not be suitable. OLS can only be used in grouped data due to the nonlinearity of the regressor and the coefficients. Therefore, for individual data a maximum likelihood technique will have to be used – a technique that is readily available in such software as Eviews and SPSS.

The main criticism that is directed against this model (as well as probit models) is the fact that it largely ignores strategic behaviour on the part of the adopters (Gourlay, 1998). Karshenas and Stoneman (1995) also argue that the model's greatest deficiency is the fact that it does not account for strategic behaviour. Whereas it is true that it does not cater for deterministic behaviour relationships, one could argue that the coefficient variance in the diffusion slope which a logit model exhibits is in itself (at least indirectly) an indication of strategic behaviour. In the present case, one has to assume that the effect of strategic thinking is minimal; indeed the relative advantage and the sheer necessity that firms have for IEPCs render strategy less relevant. Though the present model does incorporate at least two variables with strategic behaviour implications; it is possible that the perceived life expectancy of the product and the perceived level of competition prove to be important determinants, thus validating the arguments of strategic influences proponents.

An important point to consider for the above factors is the fact that most of the data they are based on are nothing more than the respondents' *perceptions* and *estimates*. With the exception of data on firm size, rate of growth, and acquisition cost the data for all other dependent variables are based on the SME managers' understanding of reality. This is a significant limitation as such estimates are subjective and are bound to be non-uniform among individual respondents. Numerous studies have used perceived respondents' values rather than more concrete economic variables (see Kauffmann, 1988; Davis, 1989; Lee, 2000; Carter and Belanger, 2003) and indeed this is a methodological shortcoming that little can be done about.

There are also great advantages to using perceived values when analysing decisions. Decisions are based on available information and strategic considerations. Our understanding of the world is influenced by:

(a) The information we receive about it;

(b) Our personal means of processing it.

Therefore, individual perceptions may differ from objective measures to the extent that they are constrained by limited information and one's personal bias. External stimuli only become relevant to decision making when they have been processed and adjusted according to the individual's behavioural norms and experiences. Logit models commonly employ perceived values when analysing a decision making process. Examples include studies on voter behaviour, housing purchase decisions and consumer choice models (Gujarati, 2002). Perceived and actual values of the same economic factors may not coincide due to imperfect information or contextual reasons (economic environment, firm's characteristics, technology's characteristics). Information spreading is central to the diffusion of innovations as both Griliches (1957) and Mansfield (1961) demonstrate and although useful for explaining the time of adoption it tells little about the decision process itself. Ideally, one should therefore seek ways to neuter the effects of information spreading on the decision to adopt. The usage of perceived values enables the present study to ignore information spreading and in doing so focus on contextual factors. In any case, information spreading for such a widely known technology as IEPCs is by definition less relevant.

Another advantage of using perceived values is that they bring the investigation much closer to the *locus operandi* of the decision making process. Perceived values are closer the decision making process as they have already gone through points (a) and (b). The fact that both perceptions and decisions take form in the mind of the same person (in this case the firm manager) ensures a certain degree of consistency necessary to make a claim of causality.

5.5 Survey Questionnaire: Design & Methodology

The primary aim of the questionnaire[109] is to collect data to be fed into the econometric model's variables. Due to the model's nature this data has to be qualitative; Bell (2000) confirms that questionnaires are an appropriate empirical data collection instrument for qualitative data. All the questionnaire's questions are structured, close-ended and the majority ask respondents to make a selection across a scale.

A special attribute of the study is that it collects perceived values for many of the variables. As a consequence several questions were designed to collect data based on the respondent's view of reality at the time of adoption or in the case of non-adoption at the time the survey took place[110]. Economic measures and technological characteristics become pertinent in decision making only if their implications are understood by managers[111]. It is therefore logical to suggest that a better

[109] The full questionnaire is supplied in Appendix 1 (a version in English followed by the original in Greek).
[110] A time which is effectively the time of non-adoption.
[111] In the very strict confines of the empirical investigation, the decision making process is paramount.

understanding of the decision making process will occur if one looks into how certain determinants are perceived to be rather than what they actually are.

The collection of perceived values was also deemed necessary due to the fact that the characteristics of the technology (compatibility, complexity, trialability, observability) could realistically only be measured via perceptions. Attention was paid to the wording of questions seeking data on perceived variables; they were designed to be concise and unambiguous so that all respondents understand them, and importantly, understand the same thing of them.

A potential problem may arise from the fact that different respondents adopt the technology in question at different points in time. Time is not an integral part of the econometric model considered. Many of the values of the variables however are likely to be different across time; e.g. industry concentration, availability of financial capital, complexity, compatibility. Added to that, variables like the cost of adoption, a firm's revenue and the technology's relative advantage are subject to inflation effects. This could complicate the analysis of diffusion if 'objective' values were to be used.

However, the very fact that the study makes use of perceived values warrants that observations made regarding events that occurred at different points in time are directly comparable. The problem of time distortion is somewhat corrected by collecting perceived values for the above determinants at the time of adoption. One thing that changes little over time is how *the effects* of some of these measures are 'felt' or perceived by decision makers. The resulting weights of different variables represent the importance of each variable *at the time of adoption*. This way the unit of analysis becomes the decision maker, at the time of adoption, rather than the economic environment or the technology itself. In any case, the small duration of the observed diffusion process (14 years) makes it less likely that any changes will be significant enough to affect overall results.

Regression using the logit model is quite flexible in the types of data it can analyse. It can test for significance both continuous or interval level variables (e.g. 1-5) and categorical level variables (qualitative data, sometimes summarised as true/false events). Deciding on the nature of the data to be collected early in the survey is a crucial factor to its success. That is because data estimation can yield useful conclusions provided that the questionnaire design adequately reflects the theoretical background of the survey. Problems may arise later on with regards to the interpretation of results[112] if for example the interval scales are not uniform.

Ideally, when dealing with qualitative data, one can employ the Likert scale, in order to ensure uniformity and representative proportionality across interval scales. The traditional ranking rationale behind the Likert scale was used in the present survey, albeit slightly changed; the traditional Likert scale seeks to ascertain how *important* the respondents think each of the determinants is in contributing to the decision to adopt. However in the present survey the questions for most variables are about how the respondents perceived each determinant to be at the time of adoption, rather than

[112] Interpreting a regression's variable coefficients is only feasible when a change in the variable by a single unit is equally proportional throughout the variable's scale. For example, for a variable ranging 1-5 an increase from 1 to 2 is no different proportionally than an increase from 2 to 3, or from 3 to 4, or from 4 to 5.

comment on its importance on their decision concerned. This way the survey detaches conceptually the determinants (independent variables) from the decision to adopt (dependent variable) and presents them to respondents as independent measures. Hence, the survey avoids implicitly suggesting a causal link (as would have been implied by the mention of the term 'importance') between the two and in doing so ensures that the respondents have not been 'guided' into a particular answer.

It should be noted that not all values collected though are perceived. Values for variables such as the size of the firm (*fsize*), the rate at which the firm is growing (*fgrowth*), whether or not it maintains linkages with MNEs (*mnelnk*) and whether a technology had been observed or tried prior to deciding (*obsrv* and *trial*) are (or are at least more likely to be, after all, they are still supplied by the respondents) based on factual information. Therefore, it would be safe to assume that they can be treated with a greater degree of confidence.

Finally, the author made the choice to collect some information that may at first appear extraneous – such as information on the adoption of a particular Internet connection method and specific applications of IEPCs. However this was deemed necessary in order to perform a more holistic descriptive analysis of the findings along with the model's estimation.

5.6 Conclusion

This chapter identified the case of a technology (IEPCs) the non-diffusion of which among Greek SMEs defied traditional explanations. The author then outlined a methodological framework for an empirical survey attempting to explain the diffusion determinants specific to the context. To aid delivery, a clear set of hypotheses were devised and a theoretical model (logit) was employed to test them. The hypotheses were informed both by theory and past empirical studies. The following chapter presents the survey's findings and the construction of an empirical model.

Chapter 6 - Empirical Survey Results

It [inference] does not exist in and by itself, but it is the result of a process [...] in inference we advance from truth possessed to further truth; and the conclusion would never be reached at all if it were not for knowledge already attained.

Francis Herbert Bradley, *The Principles of Logic*

6.1 Introduction

This chapter presents the results produced by the empirical survey as well as an attempt to analyse them quantitatively. Following the specification of model and parameters of the empirical survey in the previous chapter, here the author compares the results obtained against initial expectations as shaped by theory. Econometric estimation results in a scaled down model, indicative of trends in the survey's context. It is also in this chapter where findings are compared with those of previous studies

6.2 Rank Effects and Perceptions

The fact that not all firms adopt at the same time implies that there is something inherently different about those firms that adopt early. Rogers (1983) classifies such firms as 'innovators' and points to a great volume of studies investigating their characteristics. One may argue that the explanation for the existence of 'innovators' is two-fold:

(i) Their perceptions with regards to the technology's characteristics are fundamentally different to those of others (e.g. due to rank effects).

(ii) Some of their experiences, activities or inherent characteristics have an effect on these perceptions.

It would be perhaps advantageous to categorise these determinants according to the effect they have on perceptions. Such a categorisation allows for greater conceptual clarity in our understanding of cause and effect in the diffusion process. Hence it will be useful during the interpretation of empirical findings. Figure 6.2 presents such a categorisation. Based on the assumptions (a) and (b) one would expect a firm's perceptions of technology[113] to be partially influenced (though not determined) by its characteristics, experiences and activities. Therefore, one would expect explanatory variables relating to the firm's characteristics, experiences and activities to be more important in explaining why a firm adopted early – in other words the *speed* of adoption. This way firms can be assigned to one of Rogers' (1983) adopter categories[114] and one can compare the relationship between broad characteristics and perceptions.

Figure 6.2 – Rank effects and perceptions

Firm, Industry and Technology Characteristics		Firm's Perceptions
fsize, fgrowth, capavail, conctr, obsrv, trial	⇒	*reladv*
Firm's Experiences		*cost*
prevxp		*lifexp*
Firm's Activities		*complx*
mnelnk		*compbl*

Ultimately, the *decision to adopt* is influenced by the collective effect of these determinants. It would be safe to assume that in spite of this influence effect they are largely independent; the perception forming process is influenced by one's personal bias, education and other environmental factors that are not confined to the firm's characteristics, experiences and activities (and are also beyond the scope of this

[113] The way they see technology

[114] innovators, early adopters, early majority, late majority, laggards (Rogers, 1983)

study). Despite this supposed influence effect most variables should be sufficiently independent to allow regression as any influence on perceptions is only partial. Therefore it still makes sense to test them as a group, especially since their effect on X_i is cumulative.

6.3 Sample Data Analysis

6.3.1 Data Collected

The collection of data took place in stages; this ensured that the responses received were kept close to the intended sample. Upon completion of each stage the sectoral, size and geographic distribution of the responses was established. Depending on the extent it differed from the intended sample, corrective action was taken in the form of targeting firms (of a particular sector or size and in particular places) so as to warrant that the data collected are representative of the population.

The questionnaire survey produced 100 responses from an equal number of Greek SMEs. This sample size (100) permits econometric estimation with the maximum likelihood method (Gujarati, 2002). As is common in inferential econometrics the relatively small size of the sample when compared to the population total (509,837 companies) calls for a degree of cautiousness towards interpreting such data. Nevertheless, the exhaustive efforts of the author into ensuring that the sample is both representative and unbiased guarantee the overall inferential validity of findings. At the same time the econometric model employed for analysis (logit), only requires enough information about the characteristics of the population which are investigated, rather than a thorough small-scale version of the population.

The author performed an initial questionnaire distribution of 120 questionnaires in August 2003 which yielded 34 responses. Non-responsiveness had been higher than anticipated, which prompted a change in the data collection method; completing the questionnaires by interviewing SME managers rather than leaving the actual document for completion proved more effective. Bell (1993) also argues that this method of questionnaire completion has a generally higher response rate. It should also be mentioned that with regards to the empirical part, the original sample according to size distribution and industry proved difficult to adhere to at least in the beginning, due to firm non-cooperation. Instead the first 34 responses produced a sample dominated by firms in the retail sector followed by some intermediary services firms (real estate, stock-exchange intermediation, accounting and finance) as well as a few light manufacturers (printers and handicraft companies) and a couple of companies in the transport (shipping) sector.

The second distribution of questionnaires took place in December 2003 and involved visiting businesses in person and completing the questionnaires while interviewing SME managers. While contact details for many of these companies were obtained through official channels (Athens Chamber of Commerce, EOMMEX), a significant proportion of the respondents in the second stage occurred by means of personal recommendation (snowballing effect) thus simulating as closely as possible a random sample. The second distribution yielded another 35 responses which were primarily retail and handicraft businesses but also included 4 light manufacturing businesses, 8 in the ICT industry, 2 shipping companies and 5 firms involved with agricultural services. As a consequence the overall sample became much more representative, according to disaggregate data on the make-up of Greek SMEs obtained from National Statistics Service (1995) and EOMMEX.

In an attempt to obtain more responses from the tourism, financial intermediation and ICT sectors, further distribution was conducted via email in the period between February and March 2004. This produced another 31 responses from a variety of small firms including retail businesses, estate agents, tourist sector firms and some firms engaging in agriculture.

A few additional responses had to be excluded from analysis due to partial completion of the questionnaire. In addition there were too few answers to questions 22 and 23 (on the uses and impact of IEPC adoption) to allow any useful interpretation. On the whole though, the survey was successful in that it resulted in enough responses to model the decision to adopt.

The complete sample contained representative observations of all sizes, industries and adopter types. As is obvious from Table 2a, the sample is dominated by businesses which are involved in retail or wholesale trade (49 per cent). Other services (small consultancies, accountants, private educational institutions) along with real estate firms formed the second larger sector group together accounting for 22 per cent. Manufacturing and construction firms are also well represented. Services and manufacturing firms had the largest absolute (and relative) number of adopters, closely followed by transport and communications companies, construction and the whole services sector. However, firms in the trade and real estate sectors had a very low ratio of adopters versus non-adopters. This is hardly surprising for the trade sector as most firms are effectively family-owned shops with an aversion towards novelties (Salavou and Lioukas, 2003).

The sample also comprises of primarily very small companies, with less than 10 employees. It is immediately obvious (Table 6.1b) that up to the present moment, small firms (0-10 workers) in the sample have the lowest proportion of IEPC adopters (49/81). This is in contrast with larger firms (>11 workers) that exhibit a remarkable 100 percent adoption (19/19). This hints that long held assumptions about the importance of firm size in diffusion may also be true in the Greek SME environment.

Table 6.1 – Firm Sector, Size and Diffusion

(a) Sector comparison of companies in the sample against the population

Sector	Sample (n)	Population (n)	Sample (%)	Population (%)	IEPC Adopters (out of sector total)
Manufacturing	11	71,377	11%	14%	**9**/11
Trade: wholesale and retail	49	224,328	49%	44%	**28**/49
Hotels / Restaurants	3	61,180	3%	12%	**2**/3
Transport, Storage, Communications	6	30,590	6%	6%	**6**/6
Real Estate Management	5	45,885	5%	9%	**2**/5
Other Services	17	35,690	17%	7%	**14**/17
Construction	9	40,787	9%	8%	**7**/9
Total	100	509,837	100%	100%	**68**/100

(b) Size comparison of companies in the sample against the population

Size Group	Sample (n)	Population (n)	Sample (%)	Population (%)	IEPC Adopters (out of size group total)
0-10 workers	81	498,896	81	97.8	**49**/81
11-20 workers	10	5,783	10	1.1	**10**/10
21-50 workers	6	3,521	6	0.7	**6**/6
51-250 workers	3	1,637	3	0.3	**3**/3
Total	100	509,837	100	100	**68**/100

Population Data Source: National Statistics Service (1995)

In logistic regression proportional representation comes second to making sure that all different kinds of potential adopters are represented. Given the time and cost limitations of the study, only a relatively small number of observations could be made. Obtaining a sample that is a proportionally scaled-down version of the population distribution in such a small sample size would mean that some groups of adopters would have to be excluded (e.g. firms with more than 50 workers, which are ironically among the earliest adopters). At the same time, some could be represented (e.g. firms with 11-20 workers) but have such low absolute numbers that preclude meaningful conclusions to be drawn.

Provided that the author uses a rank based model, which looks for traits in the characteristics of firms to explain instances of adoption, it would be illogical not to observe the characteristics of such firms as they are typically amongst the first to adopt. Moreover, in the study of technological diffusion early adopters are of tremendous importance; it is by antithesis between them and technological laggards that our understanding of diffusion progresses.

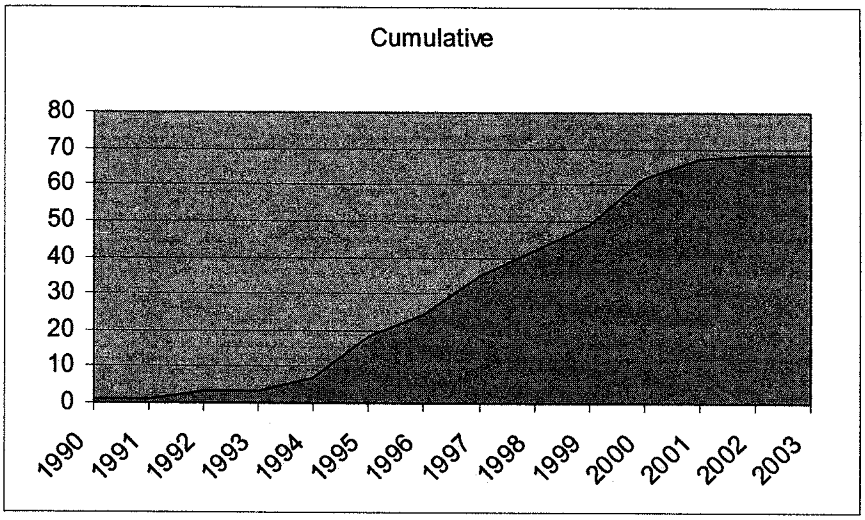
Accordingly, due consideration was given to the representation of firms of all sizes in the sample (Table 6.1) even if that means that in some cases the sample does not always reflect accurately the population distribution. Notwithstanding the above, arguably a certain measure of proportion is maintained.

With regards to the actual diffusion of the technology in question (IEPCs) a total of 68 firms had adopted by the time of the survey while the remaining 32 had not. IEPCs have diffused widely in the economy and the firms that did not adopt tend to be small retail businesses (Table 6.1) that have little or no use for such a technology.

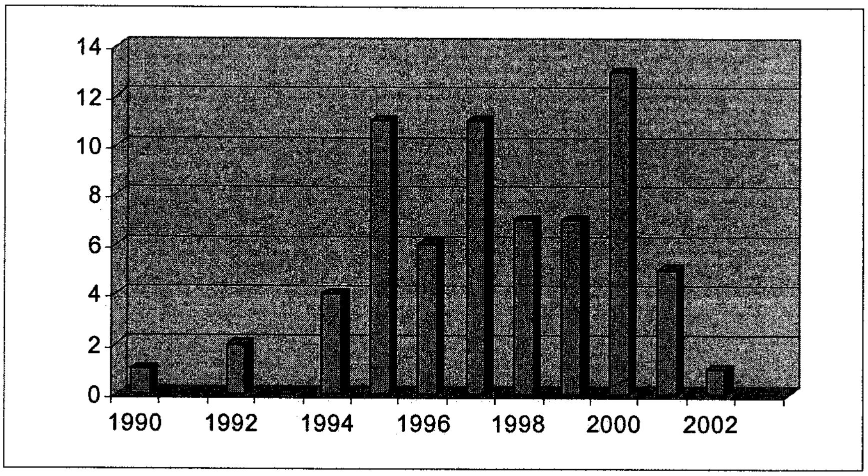
Inter-firm diffusion in the sample closely resembled Rogers' (1983) theoretical diffusion curve (Figure 6.3) as discussed earlier. An important difference from Rogers' (s-shaped) theoretical diffusion curve is the absence of a clear-cut diffusion 'take-off' period which Rogers expects when diffusion approaches 50 per cent of the potential adopters. In other words, there is no period of rapid, dramatic growth as indicated by the steepness of the slope in Figure 6.3.

Figure 6.3 - IEPC Diffusion in Greek SME Sample

(Cumulative number of adopters (Y_i=1) in sample across time)



(number of adopters per year (Y_i=1) in sample)



6.3.2 Converting Data

The following table (Table 6.2) depicts the rules adhered to when converting questionnaire responses to variable values. In the interest of clarity, the abbreviated variable (e.g. *fsize* for 'firm size') as used in estimation is mentioned along with the notional variable symbol (e.g. X_{2i}). Table 6.2 also provides a brief rationale for the conversion based on literature and the parameters of the study. In addition, each variable forms part of the test statistic of one or more specified hypotheses.

Only one variable (*fsize*) utilises an interval scale, six variables utilise ordinal scales compliant to the Likert scale convention[115] (*cost, reladv, capavail, conctr, complx, compbl*), five binary or dummy variables indicating true or false (*fgrowth, prevxp, lifexp, obsrv, trial*), while only one is categorical (*mnelnk*). The thirteen variables draw data from a total of twenty-three questions (see Appendix 1). Following cross-tabulation of individual regressors versus the regressand (Appendix 5d) distinctive trends prompted rearrangement of some of the data[116]. To allow for more extensive analysis, two of the ordinal variables (*cost, reladv*) as well as the categorical variable (*mnelnk*) were broken down to five dummy variables each.

[115] By convention the Likert scale values responses on a range of 1 to 5, with 1 being the lowest possible perception and 5 being the highest.
[116] Dummy conversion was deemed appropriate where a clustering of observations in a single value occurred.

Table 6.2 Questionnaire Responses linked to Ranked, Binary and Categorical Variable Values

Variable	Notional & Hypotheses	Ranking Value	Rationale
fsize	X_{2i} (firm size) **H1, H2**	**1** = employees ≤10 and/or* Y ≤€100,000 **2** = 11 ≤employees ≤20 and/or* Y ≤€100,001 ≤ €500,000 **3** = 21 ≤employees ≤50 and/or* Y ≤€500,001 ≤ €700,000 **4** = 51 ≤employees ≤250 and/or* Y ≤€700,001 ≤ €4,000,000 **5** = 250 ≤employees and/or* Y ≤€4,000,001 *whichever Δ% is greater	Firm size has been shown to be an important determinant of adoption. Interval scales are in accordance with the broadly accepted definition of SMEs (EC, 1996).
fgrowth	X_{3i} (firm growth) **H3**	**0** = no firm growth, or little growth **1** = firm is growing rapidly** ** where ΔY% > 10 (roughly double the value of inflation in 2003-4)	Growth in terms of revenue.
prevxp	X_{4i} (previous experiences) **H11**	**0** = no or negative previous experiences **1** = firm has had a positive previous experience of a similar technology	Testing the effect of a previous implementation of IT equipment in the period 1970-1989.
cost	X_{5i} (cost of adoption) **H12**	**1** = very low **2** = low **3** = manageable **4** = high **5** = very high Ordinal variable represented by five dummy variables:	Importance of cost of adoption relative to the firm's ability. Perceived value.

		dc5 dc4 dc3 dc2 dc1 **1** 0 0 0 0 1 **2** 0 0 0 1 0 **3** 0 0 1 0 0 **4** 0 1 0 0 0 **5** 1 0 0 0 0	
reladv	X_{6i} (relative advantage) **H4**	**1** = very low, or no relative advantage **2** = low **3** = neuter **4** = positive **5** = very high Ordinal variable represented by five dummy variables: dr5 dr4 dr3 dr2 dr1 **1** 0 0 0 0 1 **2** 0 0 0 1 0 **3** 0 0 1 0 0 **4** 0 1 0 0 0 **5** 1 0 0 0 0	Advantage yielded by technology relative to its cost. Perceived vale.
lifexp	X_{7i} (life expectancy) **H15**	**0** = not important consideration or was not taken into account **1** = important consideration	Tests whether the perceived life expectancy of a technology was an important factor in the decision to adopt. Perceived value.
capavail	X_{8i} (capital availability) **H5**	**1** = very difficult to obtain **2** = difficult to obtain **3** = average **4** = easy to obtain **5** = very easy to obtain	Availability of capital at the time of adoption, either in terms of retained profits, or from external sources (loans, mortgages, overdrafts). Perceived value.

mnelnk	X_{9i} (linkages with multinational enterprises) **H6, H7, H8, H9, H10**	**1** = no interaction whatsoever **2** = trading partner of MNE **3** = supplier to a MNE **4** = joint R&D **5** = joint HRD Categorical variable represented by five dummy variables: dm5 dm4 dm3 dm2 dm1 **1** 0 0 0 0 1 **2** 0 0 0 1 0 **3** 0 0 1 0 0 **4** 0 1 0 0 0 **5** 1 0 0 0 0	Tests the level and nature of interaction between the SME and any multinational enterprise. Sum of responses to four questions; (i) trading partner (ii) MNE supplier (iii) joint R&D (iv) joint staff development
conctr	X_{10i} (concentration) **H13**	**1** = very low, or no competition **2** = low **3** = average **4** = high **5** = very high dct5 dct4 dct3 dct2 dct1 **1** 0 0 0 0 1 **2** 0 0 0 1 0 **3** 0 0 1 0 0 **4** 0 1 0 0 0 **5** 1 0 0 0 0	Level of competition in the industry the firm operates. Perceived value.
complx	X_{11i} (complexity) **H14**	**1** = not complex at all **2** = slightly complex **3** = of average complexity **4** = highly complex **5** = extremely complex	Tests the complexity of the technology as it was perceived at the time of adoption. Perceived value.
obsrv	X_{12i} (observability) **H16**	**0** = technology not observed **1** = technology observed	Tests whether the technology in question was observed working elsewhere by a staff member of the SME.

trial	X_{13i} (trialability) **H17**	**0** = technology not tested **1** = technology tested	Tests whether the technology in question was tested by a staff member of the SME.
compbl	X_{14i} (compatibility) **H18**	**1** = not compatible at all **2** = only partially compatible **3** = mostly compatible **4** = highly compatible **5** = perfect fit	Tests the extent to which the technology was seen as compatible with the firm's existing structures and/or other technologies at the time of adoption. Perceived value.

General Notes

1. Greyed out boxes indicate that the variable is perceived; in other words the value is based on the individual respondent's judgement.
2. Smaller values are converted to smaller rankings.
3. In dummy variables, a ranking value of 0 is used meaning 'false' and a ranking of 1 meaning 'true'.

6.3.3 Sample Overview

Following the above conversion table, the data take a form suitable for quantitative analysis and econometric estimation. A summary of descriptive statistics of the resulting, dependent variable and independent ordinal, dummy and categorical variables, is presented at Table 6.3.

Table 6.3 – Survey Data: Descriptive Statistics

Dependent Variable

	n	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Y	100	.00	1.00	68.00	.6800	.46883	.220

Main Independent Variables

	n	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
fsize	100	1.00	4.00	135.00	1.3500	.74366	.553
fgrowth	100	.00	1.00	27.00	.2700	.44620	.199
capavail	100	1.00	5.00	290.00	2.9000	1.28315	1.646
conctr	100	2.00	5.00	412.00	4.1200	1.06629	1.137
mnelnk	100	1.00	5.00	213.00	2.1300	1.46097	2.134
prevxp	100	.00	1.00	27.00	.2700	.44620	.199
reladv	100	1.00	5.00	345.00	3.4500	1.47966	2.189
cost	100	1.00	5.00	357.00	3.5700	1.23301	1.520
trial	100	.00	1.00	48.00	.4800	.50212	.252
complx	100	1.00	5.00	236.00	2.3600	1.13280	1.283
compbl	100	1.00	5.00	301.00	3.0100	1.32950	1.768
obsrv	100	.00	1.00	70.00	.7000	.46057	.212
lifexp	100	.00	1.00	56.00	.5600	.49889	.249

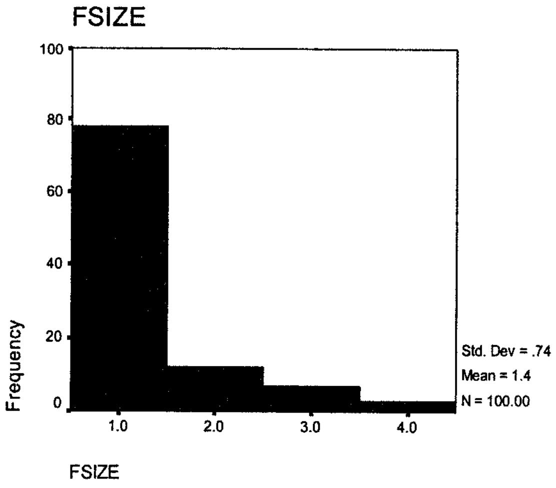
Converted Dummy Variables

	n	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
dc1	100	.00	1.00	11.00	.1100	.31447	.099
dc2	100	.00	1.00	9.00	.0900	.28762	.083
dc3	100	.00	1.00	25.00	.2500	.43519	.189
dc4	100	.00	1.00	30.00	.3000	.46057	.212
dc5	100	.00	1.00	27.00	.2700	.44620	.199
dm1	100	.00	1.00	53.00	.5300	.50161	.252
dm2	100	.00	1.00	16.00	.1600	.36845	.136
dm3	100	.00	1.00	11.00	.1100	.31447	.099
dm4	100	.00	1.00	8.00	.0800	.27266	.074
dm5	100	.00	1.00	13.00	.1300	.33800	.114
dr1	100	.00	1.00	11.00	.1100	.31447	.099
dr2	100	.00	1.00	14.00	.1400	.34874	.122
dr3	100	.00	1.00	19.00	.1900	.39428	.155
dr4	100	.00	1.00	15.00	.1500	.35887	.129
dr5	100	.00	1.00	37.00	.3700	.48524	.235
dct5	100	.00	1.00	49.00	.4900	.50242	.252

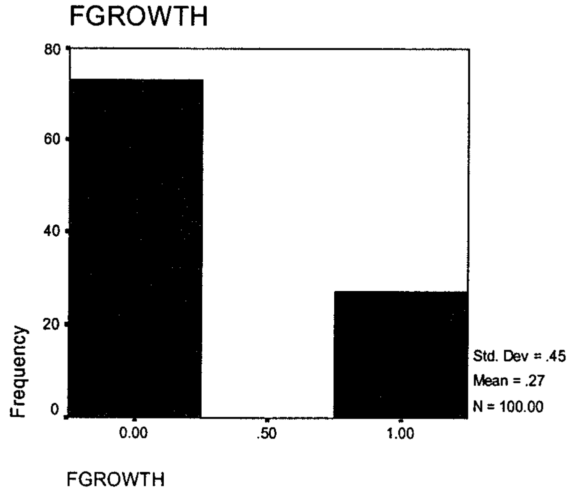
(i) Firm-Related Questions (the characteristics of firms)

The overwhelming majority of firms in the sample were small firms. In particular, data on *fsize* (figure 6.4) point to the predominance of the micro-firm (less than 10 employees) in the sample. Additionally, most firms in the sample were experiencing little or no growth. Moreover, a majority perceived the level of competition in their sector to be very high. In terms of their perceptions with regards to the availability of financial capital, most respondents stated 'average' with the rest being almost equally spread. Few firms had successful previous experiences with a similar technology. While slightly more than half of the participating firms had no linkages with MNEs the remaining were equally spread with joint R&D linkages being slightly less common.

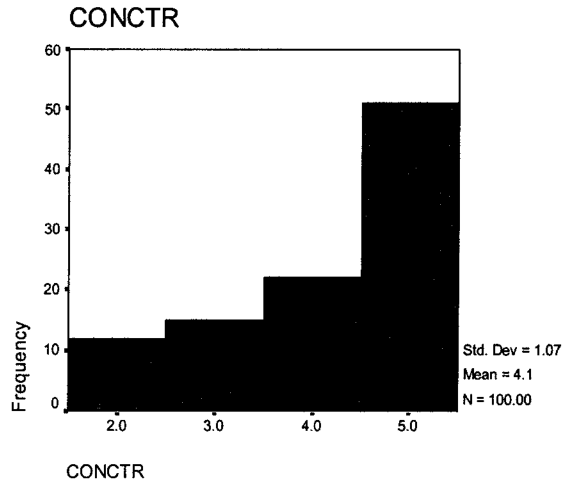
Responses to Variable *fsize*



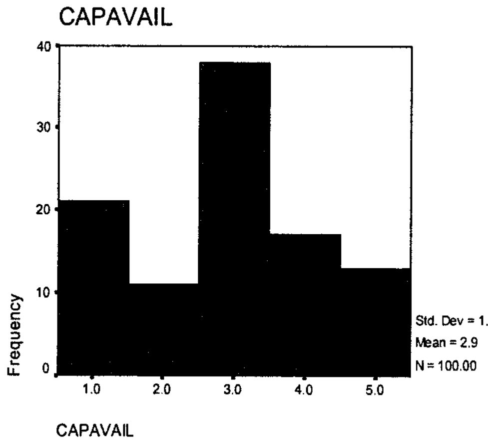
Responses to Variable *fgrowth*



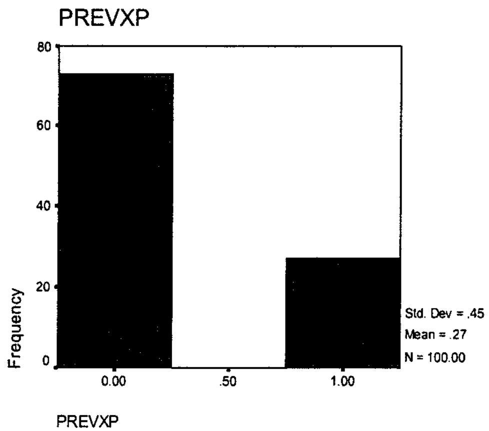
Responses to Variable *conctr*



Responses to Variable *capavail*



Responses to Variable *prevxp*



Responses to Variable *mnelnk*

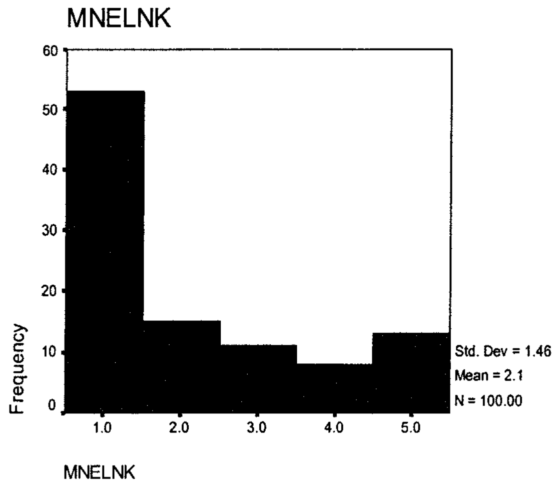
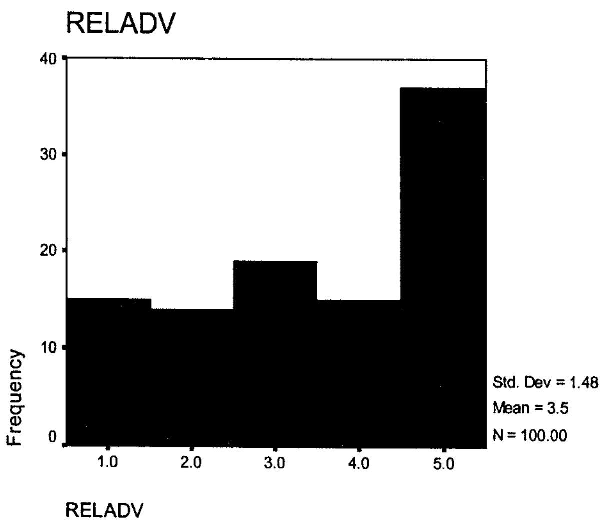


Figure 6.4 – Responses to variables *fsize*, *fgrowth*, *conctr*, *capavail*, *prevxp* and *mnelnk*

(ii) Perceptions of Technology's Characteristics

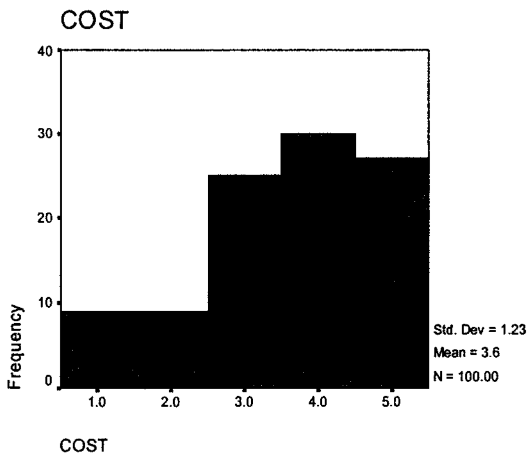
The majority of companies in the sample perceived the technology's relative advantage to be high or very high. Yet a sizeable proportion (more than 27 per cent) saw no real benefits in the adoption of an IEPC. The greatest share of all respondents perceived the technology's relative advantage to be very high (Figure 6.5).

Figure 6.5 - Responses to variable *reladv*

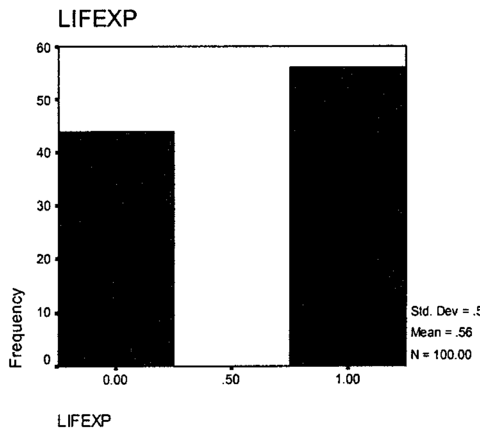


In addition, the cost of implementation of IEPCS was found to be high by most respondents (Figure 6.6). A small majority of respondents (56) stated that the technology's life expectancy was taken under consideration when making a decision on adoption. While most participants had observed the technology in action prior to making a decision, a sizeable proportion (30) did not. Responses regarding the perceived compatibility of IEPCs to existing physical hardware and operational structures were less clear-cut. A large proportion (23) saw the technology as totally incompatible; a reluctant majority though attested to the technology's average compatibility. Unexpectedly, most respondents had no apprehensions about the technology's complexity, possibly because

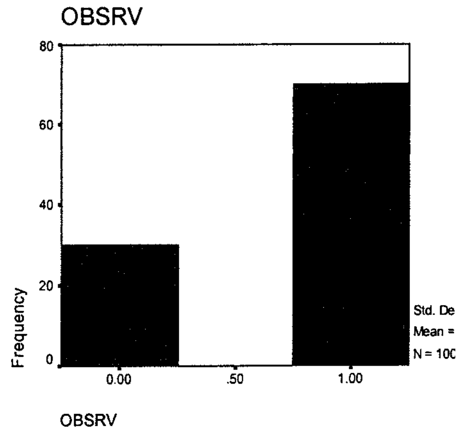
Responses to Variable cost



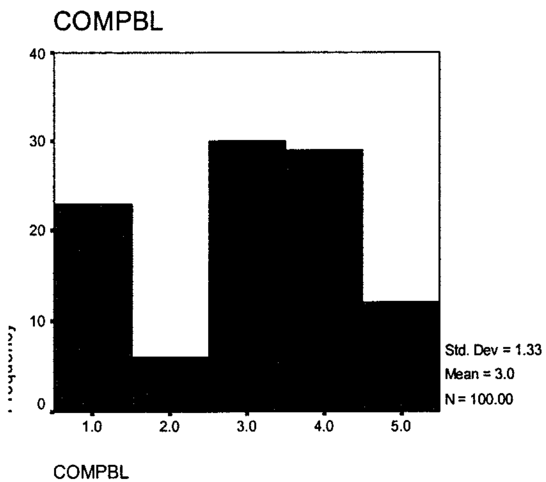
Responses to Variable *lifexp*



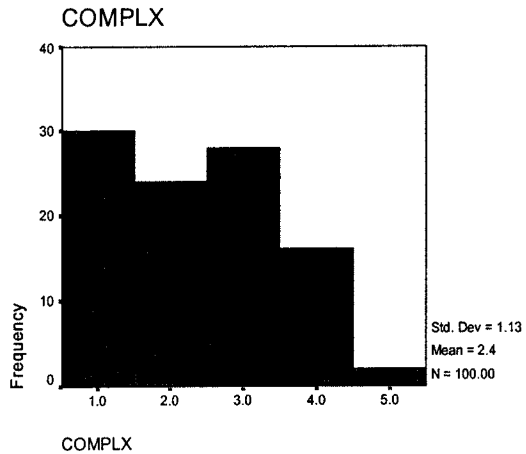
Responses to Variable *obsrv*



Responses to Variable *compbl*



Responses to Variable *complx*



Responses to Variable *trial*

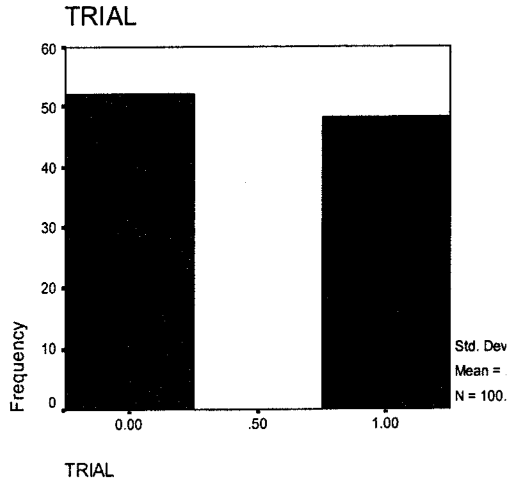


Figure 6.6 – Responses to other variables

of the technology's widespread observability. Finally, a marginal majority of respondents had not had the chance to try the technology prior to taking a decision.

6.4 Quantitative Analysis

6.4.1 Bivariate Correlations

Further quantitative analysis of the collected data may help in gaining a further insight in the research questions. This analysis may take the form of correlation tests involving each one of the independent variables against the decision to adopt (Y_i). The primary measure of association used is the *Pearson Chi-Square (χ^2)*. The Pearson χ^2 statistic test can be used to establish the individual effect of each predictor on the dependent variable (Agresti, 2002). The indicator of a statistically significant relationship between the two variables is a sufficiently low P (<0.05) value for a corresponding Pearson χ^2 (Gujarati, 2002). This is because a sufficiently low probability would lead one to reject the null hypothesis that the two variables have no statistical association.

Additionally, the *Pearson correlation coefficient (r value)* is provided. The Pearson correlation coefficient is a simple measure of association between two variables, ranging from -1 (implying a strong inverse correlation) to 1 (implying a strong positive correlation). Devore and Peck (1993) argue that the Pearson correlation coefficient[117] (r) is one of the most commonly used correlation measures. Apart from

[117] All figure provided in the present study were calculated using Statistical Package for Social Scientists (SPSS) version 11.

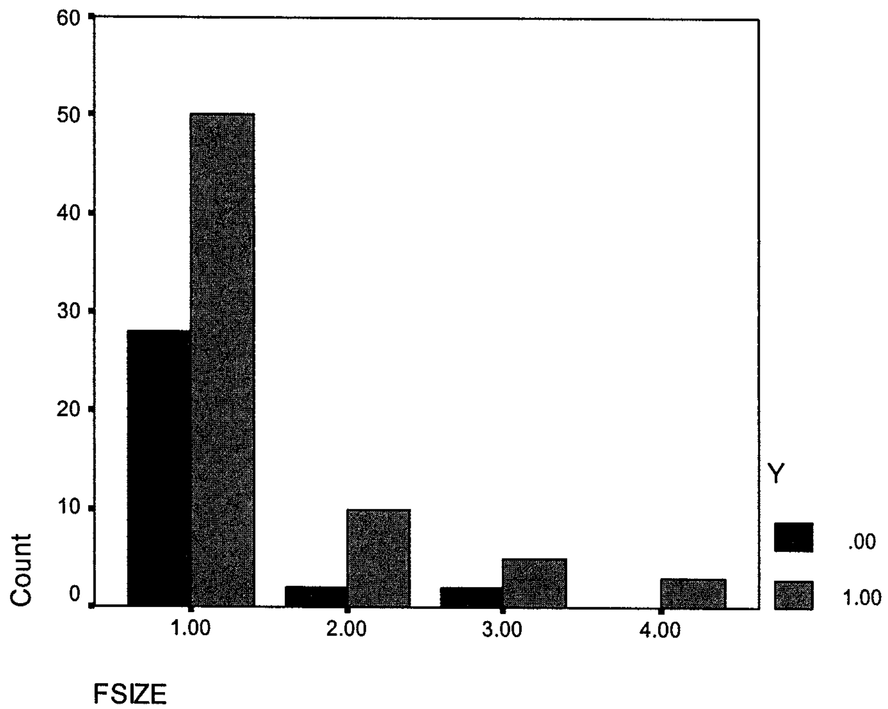
the generic Pearson r, the present context calls for a more specific correlation measure, designed to identify non-linear relationships which may otherwise be missed. The *Spearman's rank correlation coefficient (rho value)* (Devore and Peck, 1993) is such a measure. Spearman's correlation coefficient (rho) was designed with ranked values in mind, making it the tool of choice in a study concerning perceptions. Given that the application of non-linear regression (logit) is planned, the Spearman's correlation coefficient is ideally suited to test the assumption of a varied effect of X_i on Y_i.

Devore and Peck (1993) also emphasise the fact that the presence of correlation does not automatically suggest a causal relationship. Therefore, one ought to use such a measure as an exploratory aid and avoid overestimating the importance of the presence or absence of correlations with regards to the overall objectives of the study.

To begin with, a presentation of the firm and industry characteristics of adopters versus non-adopters could assist validate long-held assumptions about the influence of the size of the firm, the level of competition and the availability of financial capital. It could also pave the way for econometric analysis, highlighting suitable candidate variables for inclusion into an explanatory model.

First of all firm size does not appear to account for significant adoption differences (Pearson χ^2=3.291, statistically insignificant since P=0.1745). As a whole, the statistical association of the variable *fsize* to *y* is not strong enough (Pearson r = 0.151). Spearman's rho is at 0.157, and while still not statistically significant, the fact that its value is marginally larger than the corresponding Pearson r may hint to a non-linear relationship. Indeed, Figure (6.7) shows that firm size is only slightly more important in accounting for non-adoption in very small firms; most of the non-adopters can be found among firms with less than 10 employees (*fsize*=1). This is a finding that is common in Greek SMEs, as confirmed by Logotech (2001b).

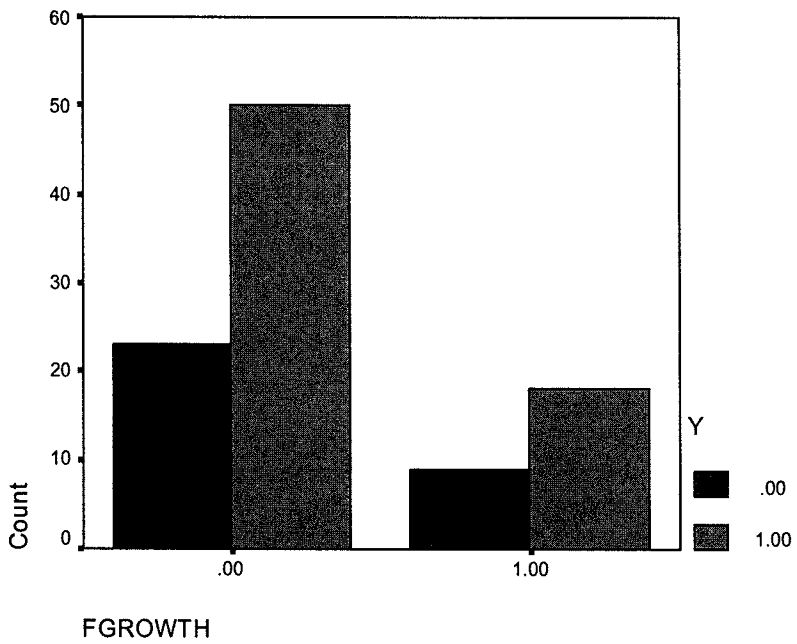
Figure 6.7 – Adopters by variable: *fsize*



Moreover, whether a firm was growing or not did not appear to have an effect on its decision to adopt the technology. The Pearson χ^2 in this case is 0.030 with a probability of 0.431 indicating that any relationship is statistically insignificant. The correlation values are so close to zero (Pearson r = -0.017, Spearman rho = -0.017) so as to preclude any form of association. Paradoxically, it appears that non-growing firms have, both in absolute and relative terms, a greater adoption record (Figure 6.8).

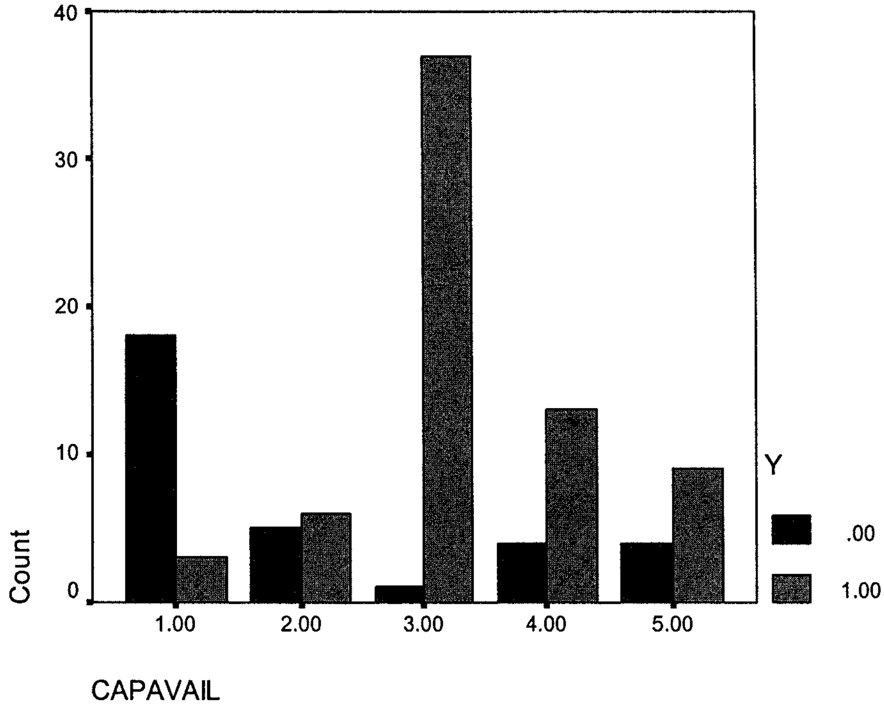
However, this is probably coincidental; this is to be expected due to the small number of growing firms included in the sample.

Figure 6.8 – Adopters by variable: *fgrowth*



To contrast with, the perceived availability of financial capital (*capavail*) to cover the cost of adoption appears to be strongly associated with the decision to adopt (*y*). The Pearson χ^2 value of 44.391 and a probability of 0.000 suggest a statistically significant relationship. Pearson r is also suggestive of a strong correlation at 0.433 which is significant at the 0.005 level. Spearman's rho is significant at 0.416, with a 0.005 significance. Therefore, the present dataset appears to corroborate established theoretical assumptions about the availability of capital. It appears that in spite of finance being more readily available in recent years, smaller firms still face significant cash flow limitations. Policy which aims to assist SMEs obtain financial capital may actually encourage diffusion. Publicly issued loan guarantee schemes (such as the ones existing in the UK) to go towards investment in technologies with proven potential could be helpful. Initiatives that aim to drive the cost of technology down, through for instance co-operative associations which utilise their bulk-buying power to claim cost and service concessions from technology suppliers are also possible solutions[118].

Figure 6.9 – Adopters by variable: *capavail*



The perceived level of competition (*conctr*) firms are faced with in their respective industries has previously been shown to influence the decision to adopt. The present data indicate a statistically significant Pearson χ^2 (10.469, P=0.075). However, both

[118] The Athens Wireless Metropolitan Network (AWMN) was setup by amateur wireless network enthusiasts in early 2001. It currently counts more than 2,700 members, offers coverage in much of the greater Athens area and has successfully negotiated the collective purchase of equipment as well as the sharing of public networking infrastructure (http://www.awmn.gr).

Pearson's r (0.158) and Spearman's rho (0.185) indicate a very weak correlation. Observing figure 6.10 one can spot the tremendous effect that a very high perception of competition (*conctr*=5) appears to have on the decision to adopt. Perhaps then it would be more meaningful to measure the effect of this very high perception of competition as distinct to that of other perception levels. To this end a dummy variable was generated, *dct5*, on the basis that *dct5=1* where *conctr=5* and *dct5*=0 otherwise.

Figure 6.10 – Adopters by variable: *conctr*

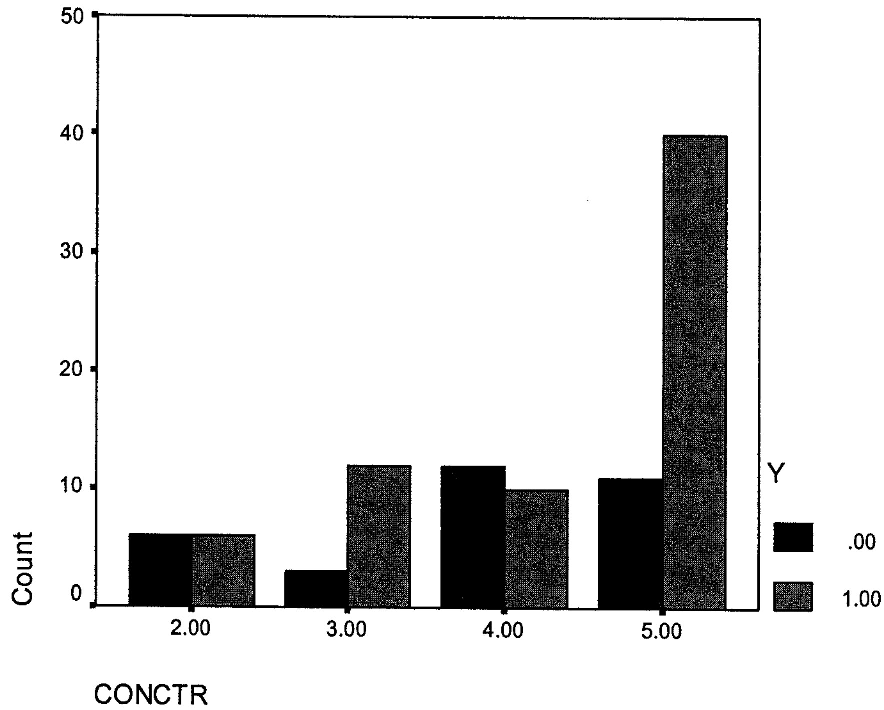
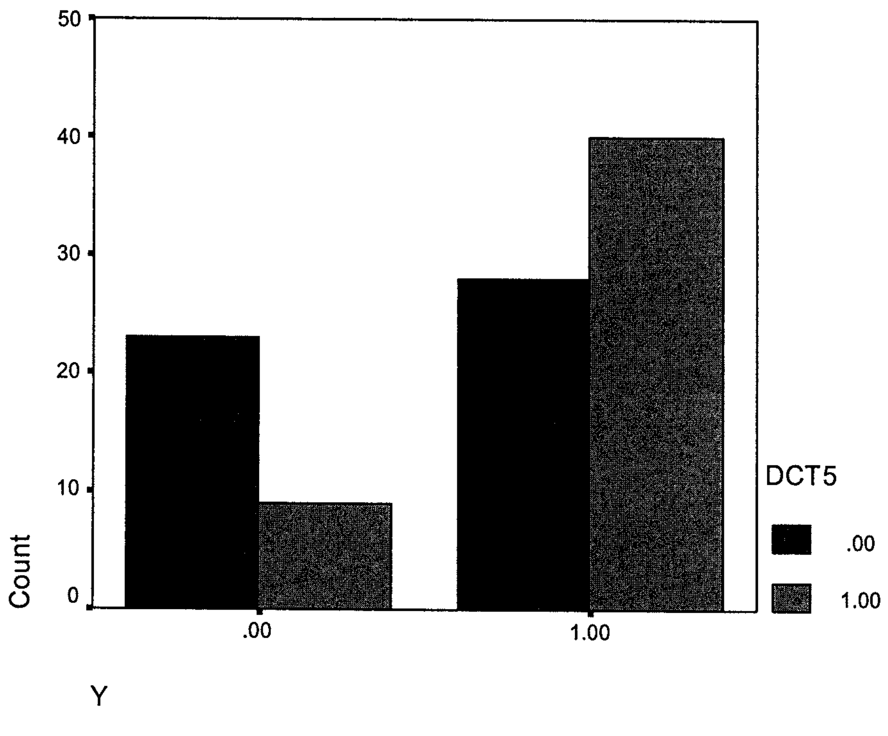


Figure 6.11 illustrates this relationship and suggests that a very high perception of competition (*dct5*=1) is highly associated with adoption (*y*=1). This is confirmed by a statistically significant Pearson χ^2 (8.206 for P=0.002). The Pearson and Spearman correlation coefficients are also statistically significant (at the 0.005 level) albeit

indicating only a weak correlation (r=0.286, rho=0.286) and the absence of outliers. The relevance of this variable could be taken as a testimony to the fact that most firms in Greece are averse to change and inflexible. The level of competition only becomes much more relevant in influencing adoption decisions when it is very high; companies only adopt when pressure from competitors forces them to.

Figure 6.11 – Adopters by variable: *dct5*



Furthermore, literature suggests that the industrial sector in which firms operate, its particular needs and characteristics, may cause some firms to be innovators and others laggards. Information about the industrial sector the participants belong to was compiled into the categorical variable *sector*[119]. Instances of adoption were more

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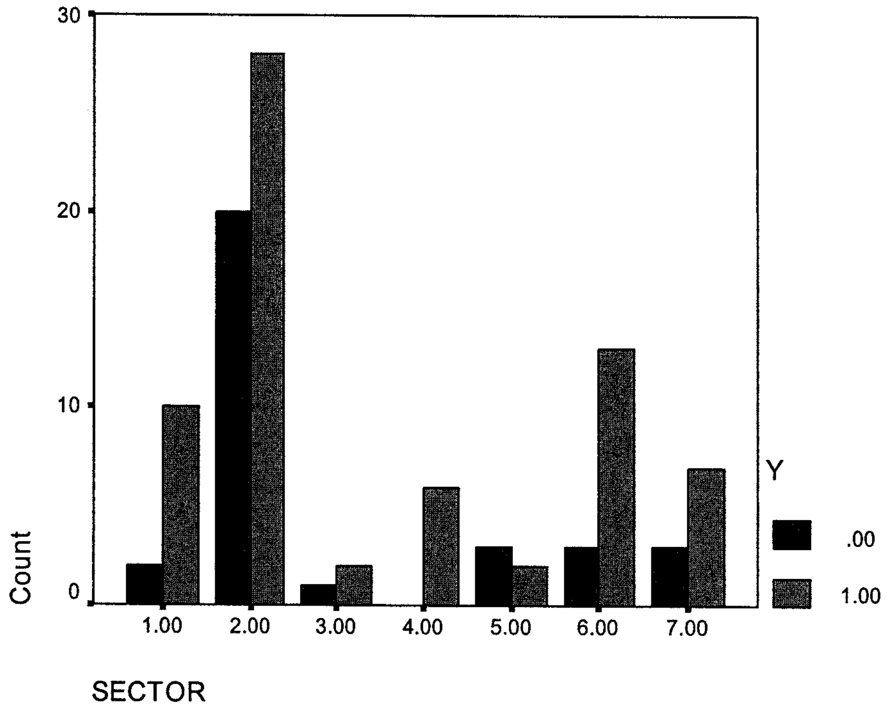
[119] Categorical values of *sector*: = 1 for manufacturing, = 2 for trade (wholesale and retail), = 3 for hotels and restaurants, = 4 transport, storage and communications, = 5 for real estate, = 6 for other services, = 7 for construction

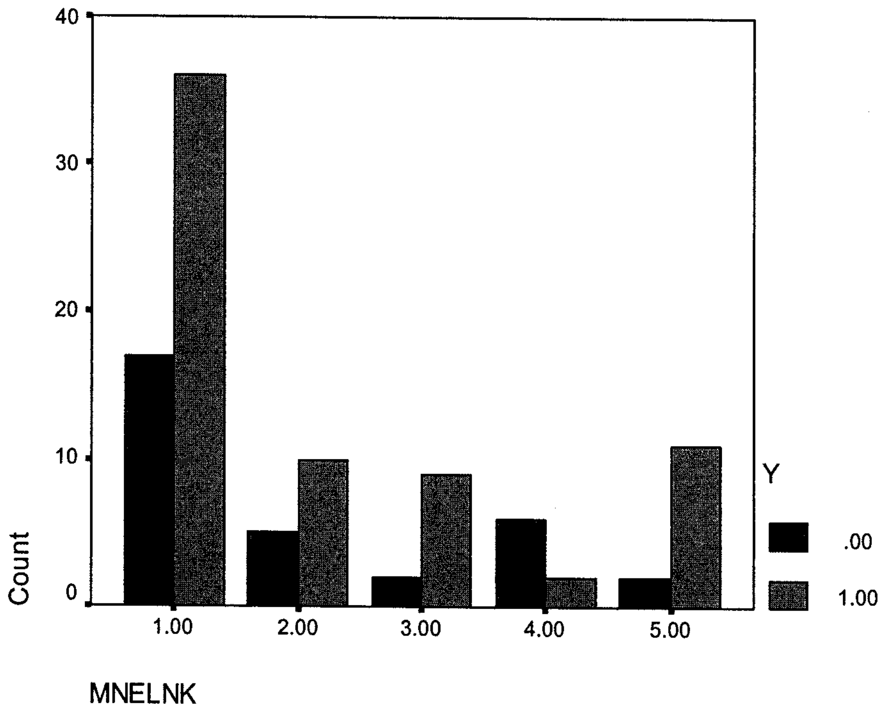
common in firms in the industries of transport, storage and communications, followed by firms in the construction industry and manufacturing.

Figure 6.12 – Adopters by sector



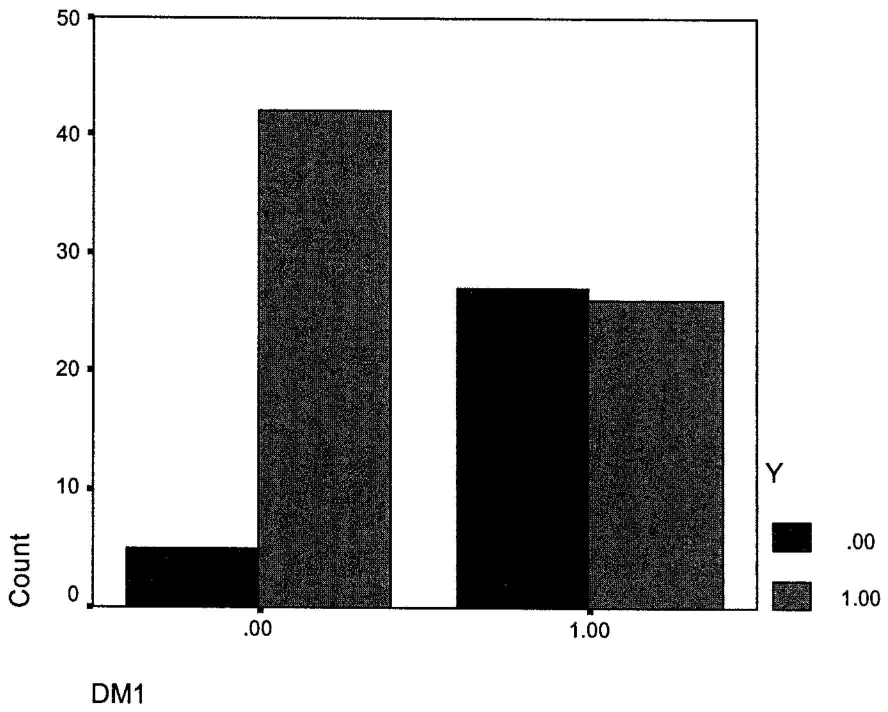
Moreover, one can test what effect, if any, linkages with multinationals may have had. The relationship is statistically significant as the Pearson χ^2 of 9.425 for P=0.0025 indicates. Observing figure 6.13, at first sight one may be surprised to notice that the absence of linkages (mnelnk=1) is indicative of a high proportion of adoption. However, such an association is hardly causal in nature. Indeed this becomes obvious if one constructs a dummy variable (*dml*) which equals 1 for *mnelnk*=1 and 0 otherwise (i.e. a value of 1 meaning no linkages, whereas a value of 0 indicating some kind linkage).

Figure 6.13 – Adopters by variable: *mnelnk*



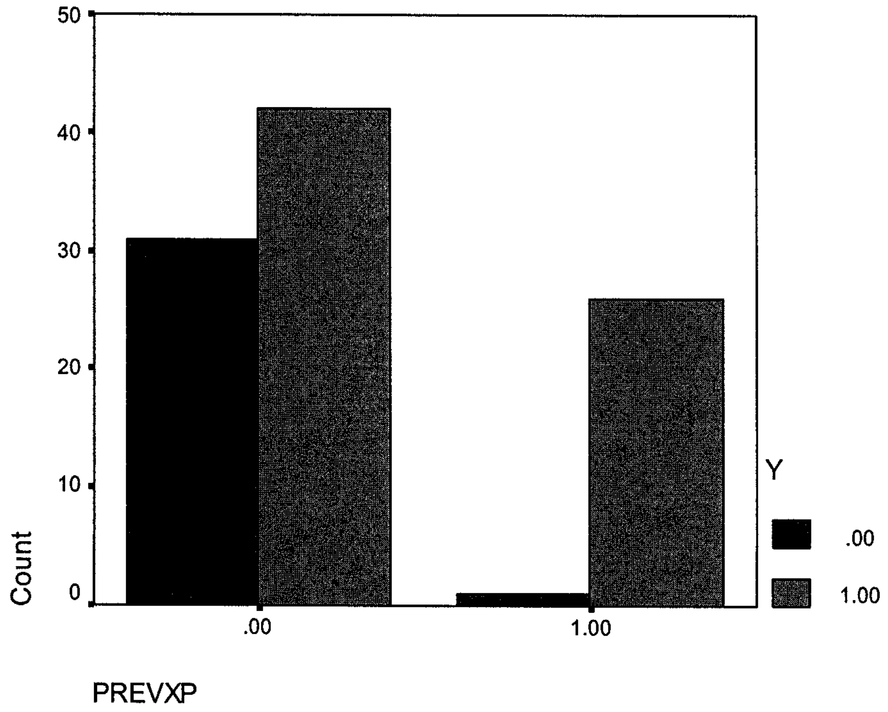
To explore the collective effect of MNE involvement a dummy variable was created, *dm1* (*dm1*=1 when *mnelnk*=1 and *dm1*=0 for all other *mnelnk* values). Figure 6.14 presents a breakdown of adopters versus non-adopters based on whether or not they interact with multinationals (*dm1*). It suggests that firms with some kind of MNE linkage (i.e. *dm1*=0), almost certainly adopted IEPCs, while the evidence is equally spread for companies with no MNE linkages (i.e. *dm1*=1). Therefore, it is plausible that many firms adopted the technology despite not having engaged in any co-operative relationship with a multinational, rather than because of it. One could deduct that having co-operative relationships with MNEs helps adoption but is certainly not a key factor.

Figure 6.14 – Adopters by variable: *dm1*



Finally, the author assumed earlier that the effect of previous positive experiences with the technology is likely to be significant. All corresponding correlation measures (Pearson χ^2 of 13.609 for P=0.000, Pearson r=0.369, Spearman rho=0.369) indicate a strong correlation between the variable prevxp and the decision to adopt Y. Observing Figure 6.15 one can notice that while the absence of experiences or negative past experiences (prevxp=0) is not conclusively associated with non-adoption, the presence of positive experiences almost guarantees adoption.

Figure 6.15 – Adopters by variable: *prevxp*



Firm characteristics and deterministic behaviour are accepted in literature as major determinants of diffusion. Table 6.4 presents a summary of the participants' profile and diffusion-related characteristics.

Table 6.4 – Summary: Profile of IEPC Adopters against Non-Adopters

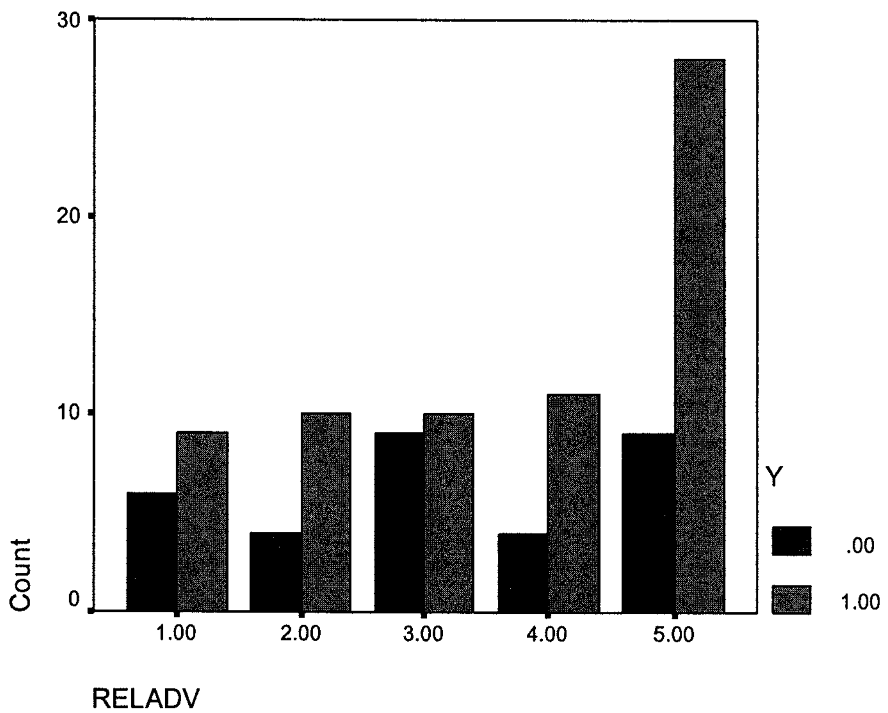
	Adopters	Non-Adopters
Size of firm	inconclusive	firms with less than 5 employees
Rate of Growth	Inconclusive	inconclusive
Perceived Level of Competition	perceive very high competition	do not feel threatened by competitors
Access to Financial Capital	easy access to financial capital	inconclusive
Industrial Sector	manufacturing, services, construction	trade, real estate
Relationship with MNEs	(mostly) had some form of linkage with a multinational enterprise	inconclusive
Previous Experiences	had previous successful experiences	had no previous successful experiences

Following the above outline of respondents' characteristics and their respective adoption tendencies, correlations are sought in terms of the importance of the technology's characteristics.

Rogers (1983) points to the technology's relative advantage (in relation to its cost) as being the key determinant in the decision to adopt. IEPCs are widely perceived as being useful; indeed this was one of the reasons for the selection of the technology in the study. This is also reflected in the current sample where 71 of the respondents perceived the relative advantage possessed by IEPCs as being either "moderate" (19), "high" (15), or "very high" (37). Among those who thought IEPCs useful, at the time of the survey there were still 22 non-adopters, pointing to the persistence of significant obstacles. Even though there is some agreement among respondents on the technology's usefulness, the data suggests that such perceptions are far from a perfect predictor of adoption (Figure 6.16).

This is confirmed statistically by a non significant Pearson χ^2 (3.777 for P=0.437) and by similarly non-significant Spearman and Pearson coefficients. With the technology widely believed to suit a variety of operational environments and it being at the centre of the press' attention the perceptions with regards to its relative advantage were not unexpected. A high relative advantage implies that the technology is seen as appropriate and one that should be adopted eventually. One can therefore deduct that the presence of strong non-adoption occurrences suggests the presence of monetary, operational and cultural barriers to adoption. It also leaves open the possibility that strategic considerations may be delaying adoption.

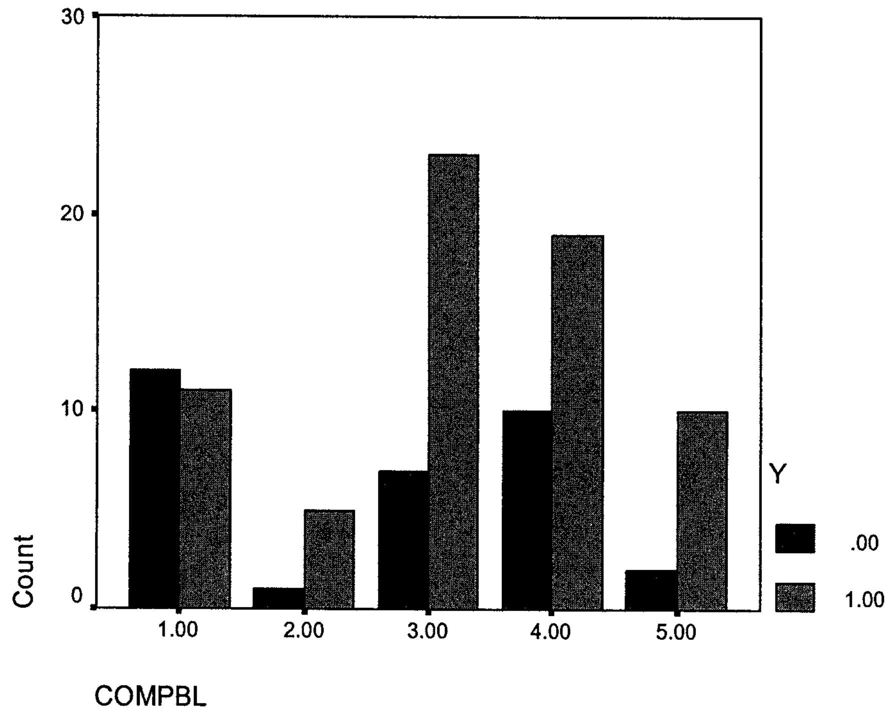
Figure 6.16 – Adopters by variable: *reladv*



Rogers (1983) argues that the perceived compatibility of an innovation with existing physical and organisational structures is a major adoption consideration – indeed one would expect that this would be particularly true in the case of IEPCs due to their flexibility as multiple purpose technologies. In the present sample the data fail to indicate such a relationship (Figure 6.17). Neither the Pearson χ^2 (7.364 for P=0.118) nor the Pearson r and Spearman rho are suggestive of a strong correlation.

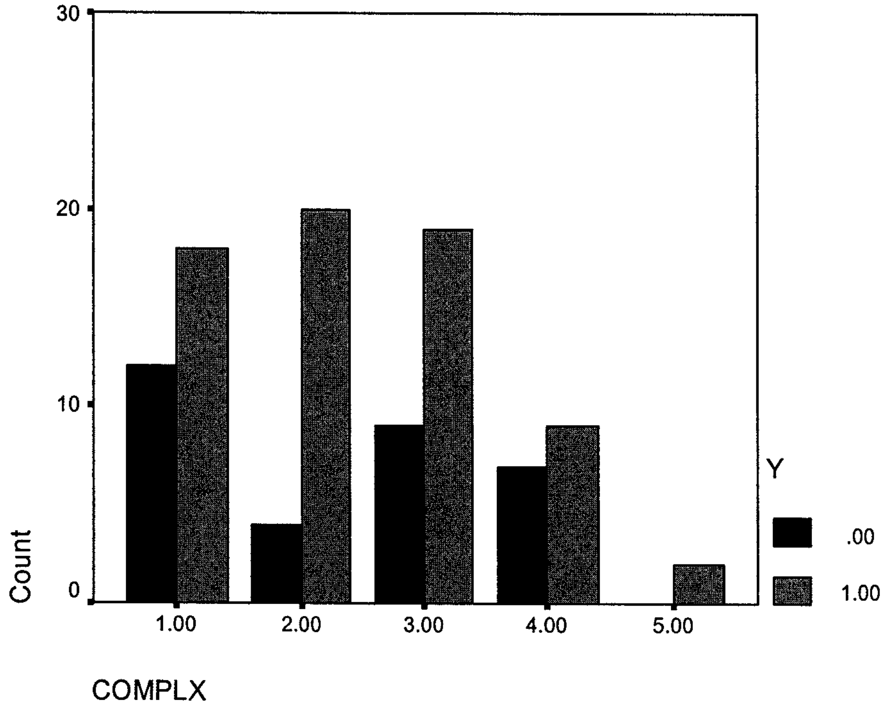
A possible explanation could be that the absence of experience with other forms of ICT prevalent in the sample (or any other technology for that matter) means that participating firm managers fail to realise the importance of compatibility; one may speculate that they are unaware of the dangers of adopting incompatible technologies and are oblivious to the production synergies created by compatible equipment.

Figure 6.17 – Adopters by variable: *compbl*



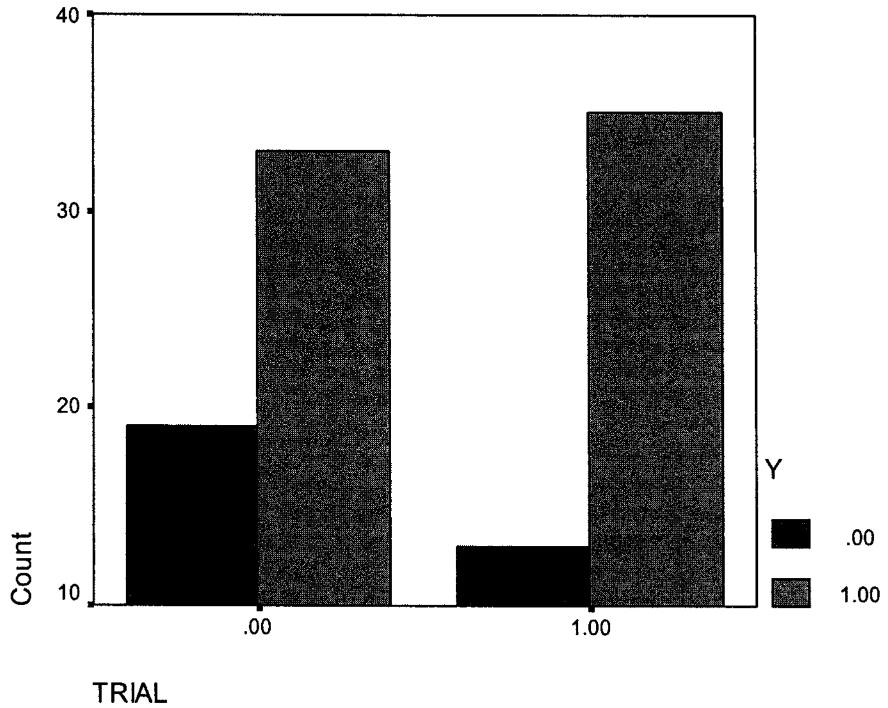
The perceived complexity of a technology is similarly thought to have an important effect on the decision to adopt (Rogers, 1983). In the present sample though, there is no evidence for such a relationship (Figure 6.18). All correlation measures are suggestive of IEPCs' adoption being independent of complexity considerations: Pearson χ^2 (5.432 for P=0.246), Pearson r=0.10 and Spearman rho=0.08.

Figure 6.18 – Adopters by variable: *complx*



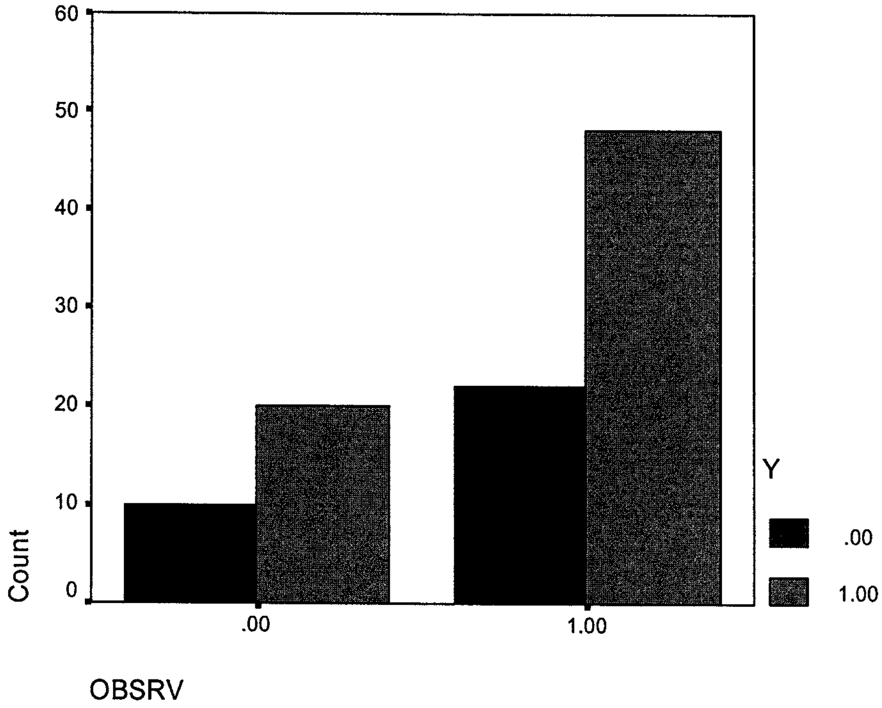
Whether a technology has been tested prior to the decision is also thought to have an effect on the decision to adopt (Rogers, 1983). This effect is captured in the variable *trial*. In the present sample though, there is no evidence for such a relationship (Figure 6.19). All correlation measures are suggestive of IEPCs' adoption being independent of previous trials: Pearson χ^2 (1.025 for P=0.311), Pearson r=0.101 and Spearman rho=0.101.

Figure 6.19 – Adopters by variable: *trial*



The degree to which a technology is observable by potential adopters is according to Rogers (1983) also a common determinant of adoption. In the present sample though, there is no evidence for such a relationship (Figure 6.20). All correlation measures are suggestive of IEPCs' adoption being unrelated to the technology having being observed: Pearson χ^2 (0.035 for P=0.852), Pearson r=0.19 and Spearman rho=0.19.

Figure 6.20 – Adopters by variable: *obsrv*

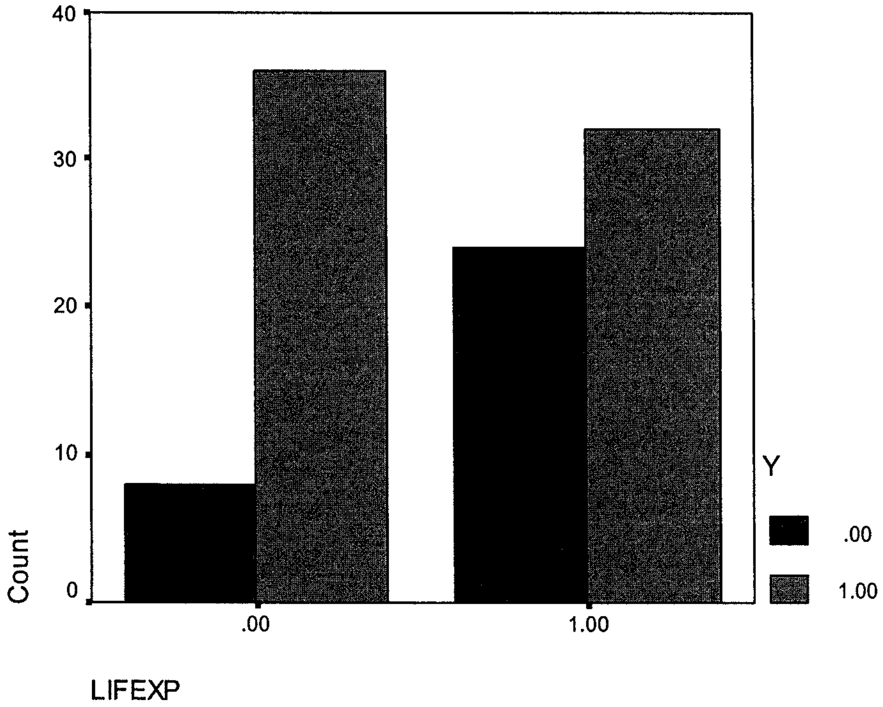


Finally it was hypothesised that the consideration of the technology's life expectancy could have an effect on adoption; specifically, given the low life expectancy of IEPCs, such a consideration should inhibit adoption. There appears to be good evidence in the present sample for a reverse relationship between *lifexp* and *Y* (Figure 6.21), albeit not a very strong one. Pearson χ^2 (6.895 for P=0.009[120]) suggests a correlation between the two measures (lifexp and Y). Pearson r (-0.263) and

[120] Note that this probability is for a two-sided hypothesis; since in the present case the hypothesis calls for one side of the relationship (i.e. high lifexp results in non-adoption), one can divide this figure by 2, resulting in a final (significant) one-sided probability of 0.0045.

Spearman rho (-0.263) also reveal the direction of the relationship, having resulted in negative figures.

<u>Figure 6.21 – Adopters by variable: *lifexp*</u>



<u>Table 6.5 - Summary: Significance of Variables</u>

Characteristics Associated with:		
adoption	**non-adoption**	**neither**
previous experiences of vintage technology, MNE linkages	difficulties in accessing financial capital, life expectancy thought important	firm size, firm growth, technology's relative advantage, observability, compatibility, complexity, trialability

6.4.2 The Question of Independence: Multicollinearity

As discussed earlier, some of the determinants of adoption included in the present study may have an effect on one another. For example, on the theoretical level, the technology's perceived relative advantage is probably influenced by the technology's cost, its life expectancy, its compatibility and even its complexity. At the same time, the relatively short time period in question and the distinct nature of the included variables could mean that they largely capture individual effects. This raises the question; are the determinant variables truly independent?

A certain degree of correlation among otherwise 'independent' variables is an accepted drawback in econometric studies in particular. This is because in contrast with experiments in nature, it is frequently impossible to actually observe such interrelationships in action; one has to rather assume their presence. The direction of such supposed relationships and the immediacy of any effects are difficult to identify. According to Achen (1982, cited in Gujarati, 2002: 348) multicollinearity in itself is not often a problem; however when it is accompanied by a low count of observations it can lead to inaccurate regression models with very high error terms.

Given the relatively low number of observations (100) in the present study it is imperative that any ambiguity regarding significantly correlated variables is settled prior to model formulation. This also has implications for the total number of regressands to be included in the final model. The problem of multicollinearity and few observations can be countered by reducing the number of explanatory variables. As such, the study, as is common in applied economics, attempts to simplify the research question by identifying broader factors – in other words it abstracts causality to its highest possible level.

Should any of the determinants be found to be significantly correlated then that would preclude the inclusion of both simultaneously in the final model. Theory permitting, only one of the two may be included. Appendix 7 presents a table with Pearson correlation coefficients for all thirteen explanatory variables.

Overall, the variables appear to be independent with no pair of variables approaching perfect multicollinearity[121] (Appendix 7). However there still exist a number of moderately correlated pairs of variables as shown in the following table (Table 6.6). Gujarati (2002) and Menard (1995) argue that there is no agreement on what the cut-off point below which variables should be excluded should be. Menard (1995) maintains that the cut-off point should be informed by the theoretical background of the research as well as the sample size. Where there is strong theoretical backing for considering the effect of a variable to be independent then the cut off point should be higher, while in cases with too few observations the cut-off point should be lower. For the purposes of collinearity testing, a Pearson's r above 0.8 indicates strong collinearity (Devore and Peck, 1993).

[121] The software package used for econometric estimation safeguards against the problem of perfect or singular collinearity; where present, Eviews 4.0 detects it, warns the user and prevents model estimation.

Table 6.6 – Pearson's R Collinearity

variables	Pearson r	variables	Pearson r	variables	Pearson r
fsize-fgrowth	0.290	fsize-mnelnk	0.292	fsize-reladv	0.38
fsize-cost	-0.340	capavail-dm1	-0.324	fsize-trial	0.302
conctr-reladv	0.336	conctr-compbl	0.348	compbl-mnelnk	0.529
dm1-prevxp	-0.510	reladv-trial	0.508	reladv-compbl	0.598
reladv-cost	-0.468	reladv-mnelnk	0.430	complx-obsrv	0.402
compbl-reladv	0.598	compbl-mnelnk	0.529	obsrv-trial	0.541

The author anticipated a degree of influence (see §6.2) particularly among the variables referring to the firm's characteristics, experiences and behaviour on one side and its perceptions about the technology's characteristics on the other. Hence, at least conceptually, a degree of correlation is to be expected. It is important to state at this point that the presence of two collinear variables in a single model need not always be detrimental; where theory and logic suggests a slight influence of one variable to another yet data warrant that there is enough distinct information to treat the variables as separate, even correlated variables can be included.

6.5 Econometric Estimation

6.5.1 The Fitted Model

The thirteen independent variables were tested for statistical significance against the dependent variable (Y_i) using a logit model and the maximum likelihood estimation method in Eviews 4.0. The software creates a model that is a reasonably good fit for the data by performing a number of iterations. The iterative process involves a first run of the model with tentative coefficient values and continuing by performing numerous iterations until convergence has occurred. The author began estimation by testing a model that included all thirteen explanatory variables (Figure 6.22).

Figure 6.22 – Thirteen Variables Model (Eviews 4.0 Output)

Dependent Variable: Y, Method: ML - Binary Logit (Quadratic hill climbing)
Included observations: 100, Convergence achieved after 5 iterations

Variable	Coefficient	Std. Error	z-Statistic	Prob.
constant	-2.970175	2.641673	-1.124354	0.2609
capavail	0.963744	0.293616	3.282322	0.0010
compbl	0.712636	0.400418	1.779730	0.0751
complx	-0.094908	0.295910	-0.320734	0.7484
conctr	0.340145	0.303833	1.119514	0.2629
cost	-0.501032	0.342635	-1.462289	0.1437
fgrowth	-1.375679	0.867723	-1.585390	0.1129
fsize	0.657131	0.609909	1.077425	0.2813
lifexp	-0.619551	0.670528	-0.923975	0.3555
mnelnk	-0.043228	0.281829	-0.153384	0.8781
obsrv	0.244155	0.903644	0.270189	0.7870
prevxp	3.172411	1.201212	2.641009	0.0083
reladv	-0.130729	0.349405	-0.374147	0.7083
trial	-0.976802	1.047382	-0.932613	0.3510

Mean dependent var	0.680000	S.D. dependent var	0.468826
S.E. of regression	0.361386	Avg. log likelihood	-0.371743
Sum squared resid	11.23158	McFadden R-squared	0.406986
Log likelihood	-37.17425	LR statistic (13 df)	51.02539
Restr. log likelihood	-62.68695	Probability(LR stat)	1.99E-06
Obs with Dep=0	32	Total obs	100
Obs with Dep=1	68		

As is obvious from the high probabilities in Figure 6.22, such a model proved unworkable. The search continued by narrowing down the model to the most relevant variables. The search for a suitable working model was informed by the bivariate correlation results and constrained by significantly correlated determinants. Thus, a number of alternative models were tested and by the process of elimination[122], convergence was reached at the following model;

$$Y_i = \beta_1 + \beta_2\, dct5_i + \beta_3\, lifexp_i + \beta_4\, prevxp_i + \beta_5\, dm1_i + \beta_6\, capavail_i + u_i \quad \textbf{(6.1)}$$

The resulting model explanatory variables are in agreement with those highlighted in earlier quantitative analysis as statistically significant. The statistic output from Eviews 4.0 is presented in Figure 6.4. The resulting model lends credence to hypotheses H5, H6, H11, H13 and H15. More specifically, five variables showed statistical significance; *dct5* (a dummy indicating conctr=5), *lifexp*, *prevxp*, *dm1* (a dummy indicating mnelnk=1), *capavail* (Figure 6.22).

Figure 6.23 – Final Fitted Model (Eviews 4.0 Output)

Dependent Variable: Y, Method: ML - Binary Logit (Quadratic hill climbing)
Included observations: 100, Convergence achieved after 6 iterations

Variable	Coefficient	Std. Error	z-Statistic	Prob.
constant	-0.358951	1.058170	-0.339218	0.7344
dct5	1.901461	0.656764	2.895196	0.0038
lifexp	-1.670513	0.644079	-2.593645	0.0095
prevxp	2.362754	1.222115	1.933332	0.0532
dm1	-1.564352	0.692526	-2.258907	0.0239
capavail	0.728149	0.243356	2.992118	0.0028

Mean dependent var	0.680000	S.D. dependent var	0.468826
S.E. of regression	0.343776	Avg. log likelihood	-0.370021
Sum squared resid	11.10911	McFadden R-squared	0.409733
Log likelihood	-37.00206	Count R-squared	0.860000
Restr. log likelihood	-62.68695		
LR statistic (5 df)	51.36976		
Probability(LR stat)	7.26E-10[123]		
Obs with Dep=0	32	Total obs	100
Obs with Dep=1	68		

[122] (3) resulted after eliminating other models which were not as good at minimising the errors of prediction and providing a good fit for data.
[123] 7.266416038432e-10 = 0.0000000007266416038432

On evaluating the resulting statistics, one may start from the null hypothesis that the independent variables are not good at predicting the dependent variable Yi. The probabilities that the null hypothesis is true are presented in Figure 6.22. Probabilities for all of the five variables (dct5, lifexp, prevxp, dm1, capavail) are all at less than 10 per cent, thus leading to a categorical rejection of the null hypothesis. This is a first indication that these variables are viable candidates for explaining the instances of adoption. Menard (1995) argues that an acceptable logistic regression model must also minimise the errors of prediction. Observing Figure 6.22 one can see that the model's standard error is a relatively low 0.343.

Goodness-of-fit tests indicating how good a fit the model is for the data are also an indication the model's ability to minimise prediction errors. By convention, in logit models the **McFadden $\boldsymbol{R^2}$** likelihood ratio index is the primary indicator of goodness of fit; with a McFadden R^2 value of 0.409 the model exhibits an adequate goodness of fit (Gujarati, 2002).

Menard (1995) points out that the frequency of correct versus incorrect predictions is another important indication as to how well the model works. According to Gujarati (2002) a comparatively simple goodness of fit measure is the **Count $\boldsymbol{R^2}$**, given by the ratio of the number of correct observations versus the total number of observations. Count R^2 for (3) is 86/100 = 0.86 indicating that the independent variables are relatively good at explaining instances of adoption.

The Likelihood Ratio-Statistic (LR-Statistic[124]) is commonly treated as a χ^2 statistic and is essentially a test of the null hypothesis that $\beta 1 = \beta 2 = \ldots = \beta n = 0$ for the logit model (Menard, 1995). The value of the LR-Statistic for (3) is 51.369; in the case of the LR-Statistic the null hypothesis can be rejected provided that it is accompanied by non significant probability (p $\leq$0.05). The low probability (P= 7.26E-10) allows the rejection of the null hypothesis that information about the regressands does not result in better predictions than those with only the constant. Another goodness-of-fit test is the **Hosmer and Lemeshow (HL)** test, which acts as indication of the closeness of expected and observed values. With the value of the HL Statistic being 11.9291, the probability is sufficiently high (Prob. Chi-Sq(8) = 0.1544) to allow one to reject the null hypothesis (Figure 6.23). Therefore, there is strong evidence that (3) is a good fit for the data.

Figure 6.24 – Hosmer and Lemeshow (HL) Test (Eviews 4.0 Output)

Dependent Variable: Y
Method: ML - Binary Logit (Quadratic hill climbing)
Date: 07/14/04 Time: 01:19
Sample: 1 100
Included observations: 100
Grouping based upon predicted risk (randomize ties)

	Quantile of Risk		Dep=0		Dep=1		Total	H-L
	Low	High	Actual	Expect	Actual	Expect	Obs	Value
1	0.0539	0.0539	10	9.46123	0	0.53877	10	0.56945
2	0.1055	0.3360	9	7.36140	1	2.63860	10	1.38233
3	0.3360	0.5561	4	5.72272	6	4.27728	10	1.21243
4	0.5649	0.7075	4	3.53569	6	6.46431	10	0.09433
5	0.7289	0.7721	0	2.58104	10	7.41896	10	3.47899
6	0.8020	0.8612	2	1.55514	8	8.44486	10	0.15069
7	0.8694	0.8866	1	1.18519	9	8.81481	10	0.03283
8	0.8866	0.9851	2	0.48961	8	9.51039	10	4.89925
9	0.9851	0.9972	0	0.08710	10	9.91290	10	0.08786
10	0.9977	0.9995	0	0.02088	10	9.97912	10	0.02092
		Total	32	32.0000	68	68.0000	100	11.9291

H-L Statistic:	11.9291	Prob. Chi-Sq(8)	0.1544
Andrews Statistic:	44.1863	Prob. Chi-Sq(10)	0.0000

124 Sometimes also referred to as G_M in literature.

6.5.2 Interpretation of Independent Variable Coefficients

Having demonstrated the validity of the model, focus will now shift on the individual variables and the extent to which they help corroborate the set of hypotheses made. The model coefficients are partial slope coefficients; According to Gujarati (2002) each of them measures the change in the estimated logit for a unit change in the value of the given regressor - assuming all other regressors constant. Though in this form the coefficients do not give away the weight of each variable, they do explain the direction of the relationship between each of the explanatory variables and the dependent. As the coefficients supplied at Figure 6.4 are logarithmic representations, their only meaningful interpretation in this form would be with regards to their sign. Both Menard (1995) and Gujarati (2002) point out that a positive coefficient indicates a positive relationship between the predictor and the dependent variable, while a negative sign indicates an inverse relationship.

Therefore, if one substitutes β for the estimated coefficients the conditional probability of adoption Y_i equals:

$$-0.358951 + (1.901461 * dct5_i) + (-1.670513 * lifexp_i) + (2.362754 * prevxp_i) + (-1.564352 * dm1_i) + (0.728149 * capavail_i) + u_i \qquad \mathbf{(6.3)}$$

Thus (6.3) suggests that intense competition, successful previous experiences and the availability of financial capital positively predispose the decision to adopt. The opposite is true for firms that perceive the life expectancy of the technology as important and have no linkages with MNEs. Comparing the expected signs to those actually observed as portrayed in Table 6.7, assists in relating the results to hypotheses made earlier. The resulting model lends credence to hypotheses H5, H6, H11, H13 and H15.

Table 6.7 -Expected and Actual Variable Signs

variable (symbol)	expected sign	observed sign
dct5	+	+
lifexp	-	-
prevxp	+	+
dm1	-	-
capavail	+	+

A more useful interpretation of the estimated coefficients can be carried out by means of odds; that is the odds that an increase by a single unit in one variable (holding all other variables constant) will cause the firm to adopt the technology (P_i =1). Since the supplied coefficients are logarithmic expressions, the conditional odds for each variable are calculated by exponentiation. For the non-binary variable *capavail* the odds have been computed at the overall means of the dataset, while the rest of the variables were held constant at 0. Table 6.8 presents the calculated odds.

Table 6.8 – Odds of the Marginal Effects on P_i

Notional	Variable	Estimated Odds
β_2	*dct5*	6.695661
β_3	*lifexp*	0.188150
β_4	*prevxp*	10.620142
β_5	*dm1*	0.209223
β_6	*capavail*	8.261702

6.5.3 Corroborating Hypotheses

Relating specific hypotheses to topical variables is now possible in order to support or reject them. What follows is an outline of accepted hypotheses made earlier in the order of importance suggested by the fitted model.

> (i) **H11**: *Firms that adopted an earlier generation of the technology and considered the experience as beneficial are more likely to adopt, whereas firms with no previous or negative previous experience of an earlier generation of the technology are less likely to adopt.*

To begin with, the positive sign in β_4 suggests a positive relationship between the existence of successful previous experiences and the probability of technology adoption. Indeed, in the current sample, its presence is crucial to the decision to adopt. As indicated by the converted odds ratio, firms that had successfully implemented a technology of similar nature in the past were as much as (approximately) 10 times more likely to have adopted. With the hypothesis being two-tailed though, the model implies one should accept only one direction of the hypothesis. While it is true that firms with positive previous experiences had a better chance of adoption the opposite cannot be said to be true; there is insufficient evidence to suggest that firms with negative or no previous experiences were less likely to adopt.

This remarkable positive effect on the decision to adopt could have resulted from Colombo and Mosconi's (1995) cumulative 'learning effects'. However, prior implementations of IT were significantly different in nature and characteristics[125]. Any operational experience gained from the use of an earlier vintage form of the technology would be of little use in the case of IEPCs, thus making the assumption of learning effects appear less credible.

One should consider that the variable represents comments not simply on the existence of previous experiences but, importantly, on the *success* of previous implementations. In contrast with Colombo and Mosconi's (1995) learning effects, its effect on X_i is not cumulative. Learning effects are more relevant where the user of the technology is also the decision maker. However in several instances decision makers are detached from everyday use of the technology; what is relevant to them is the extent to which the technology has been successful in delivering the desired and expected benefits.

Therefore, in the present case, this important effect may be attributed to the indirect (singular, one-off) effect previous successful experiences may have had in the technology's relative advantage. In other words, the fact that these implementations were viewed as successful may have altered in some way the adopters' belief as to the technology's suitability[126].

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[125]Marketable microcomputers in the period 1970-1989 had little or no networking capabilities, no standardised operating systems (a multiplicity of different platforms competed for market dominance) and fulfilled very different needs (automated tasks, basic data retrieval, calculations).

[126] In informal discussions with SME managers the author observed that those participants who had successfully implemented earlier technologies felt 'greater confidence' and 'less uncertainty' towards

(ii) **H5**: *The availability of financial capital facilitates adoption while the lack of financial capital discourages it.*

The variable *capavail* is a measure of the perceived availability of financial capital ranging from 1 (=capital very difficult to obtain) to 5 (=capital very easy to obtain). The positive sign in the coefficient β_6 (*capavail*) suggests a positive relationship between the perceived availability of financial capital and the probability of technology adoption. The converted odds ratio indicates that, other things remaining the same, an increase by a single unit in the firm's perception of financial capital availability increases the odds of adoption approximately eight times ($e^{\beta 6} \approx 8.26$). This is in line with the findings of Stoneman (1976) regarding the diffusion of computers and Cobham (1999) regarding the technology decisions of SMEs. The confirmation of H5 suggests that technological diffusion in modern Greek SMEs is encouraged by the increased availability of financial capital. The fact that it is the second most important variable in terms of magnitude on the overall odds of adoption is an indication of the continuing relevance of finance, despite its purported increased availability.

(iii) **H13**: *Firms that perceive their industry as 'competitive' are more likely to adopt while firms that perceive little competition in their industry are less likely to adopt.*

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adopting. With Greek SMEs being highly risk averse, the element of a positive previous experience may have been crucial in alleviating fears and thus reducing perceived risk.

The positive sign in the coefficient β_2 suggests a positive relationship between a high perception of competition and the probability of technology adoption. The converted odds ratio, indicates that firms that perceive their environment as being highly competitive are almost four times more likely to have adopted. It should again be noted that only part of hypothesis H13 can be accepted on the basis of the model; there is no evidence that firms which thought of their industry as being less competitive are less likely to adopt. The relatively high odd value ($e^{\beta 2} \approx 6.69$) may be an indication of how perceptions as to the necessity of a technology change on the face of increased competition. This is in accordance with the findings of Goel and Rich (1997). Strategic effects are well documented in literature; the present evidence seems to corroborate the influence of strategic considerations as identified by Karshenas and Stoneman (1995). The imperative for modernisation seems to become greater when managers see their companies threatened by increased competition. The adoption of a technology in such a scenario is a viable form of differentiation.

(iv) **H6**: *SMEs that engage in any co-operative relationship with multinational enterprises are more likely to adopt the technology while firms that do not co-operate with multinationals are less likely to adopt.*

The negative sign in the coefficient β_5 suggests that firms which do not engage in any co-operative relationship with MNEs are less likely to adopt. The converted odds ratio of 0.20 suggests that MNE linkages, where present, have a comparatively moderate effect on the decision to adopt. In any case the association confirms that firms which are suppliers, direct customers of MNEs or co-operate with them in either training or research and development have a higher chance of adoption. This occurs through vertical technology transfer; literature has documented well instances of technological spillover from MNEs to host countries and evidence suggests that this is also true for the present case.

(v) **H15**: *Technologies with a low life expectancy are less likely to be adopted.*

Modern computers have a very short life cycle. Just like any other case, technology substitution in the personal computer market is frequently prompted by the development of more advanced products. However, unlike most technologies the existence of network effects, complementarity and the need for compatibility with the technology that industrial partners are using may prompt substitution of the technology faster than would otherwise be necessary[127]. The negative sign in the coefficient β_3 suggests an inverse relationship between the variable on the importance of life expectancy and the probability of technology adoption. The converted odds ratio of 0.18 indicates that those firms which considered the (small) life expectancy of the technology were less likely to adopt.

[127] The release of a new operating system may often provide few relevant benefits to most firms. Companies however, may have to upgrade anyway in order to ensure compatibility as everybody else upgrades and as complementary products (hardware and software) assume the presence of a majority technology. In other words, had it not been for everybody else moving on to the newest incarnation of the technology the firm could well have its needs served by the earlier technology.

The negative relationship identified by the model may also be related to the risk aversion traditionally demonstrated by Greek SME managers. Informal discussions with SME managers revealed that many of them are afraid they cannot afford the burden of rapid and continuous technology substitution. A burden that is not simply financial but also involves commitment to continuous learning. With most of these firms having extremely limited resources both in financial and human terms, understandably a technological catch-up game may not sound appealing.

There is insufficient evidence to support any of the remaining hypotheses[128].

The implications of the results for policy making are important; instead of directly funding the purchase of equipment public funds may be better spent in changing managers' perceptions towards the adoption of innovations. Encouraging linkages with multinationals could also yield positive results. Input-centred diffusion initiatives at both the national and European level could improve their efficiency by subsidies targeted to different types of SMEs. Focusing on companies with no previous experiences may assist in the diffusion of IEPCs into those companies which are less likely to adopt. Targeting incentives at smaller firms in highly concentrated industries could lower costs for new entrants and thus promote competitive dynamism.

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[128] See discussion in the section that follows (§6.5.4)

6.5.4 Rejected Hypotheses

The fitted model corroborates a relatively small number of theoretically viable hypotheses. This is an interesting finding on its own right, and especially so, when the remaining hypotheses have been previously shown empirically to be valid. Nonetheless, cautiousness is needed when drawing conclusions on the basis of the null hypothesis; lack of evidence is not, by itself, conclusive proof of functional independence. The relatively small number of observations placed limits on the number of endogenous variables. Therefore any tentative inferences made henceforth, are of a speculative nature.

Indeed, the peculiarities of the observed context account for the most part for the rejection of hypotheses concerning firm size and growth (H1, H2 and H3). As shown in Figure 6.7, the vast majority of partisans were micro-firms and there was an unexpected persistence of the adoption/non-adoption spread even in higher size bands (where *fsize* = 2, 3). No trend can be discerned from the firm growth variable (*fgrowth*), which may lead to one to speculate on the importance of strategic and even cultural factors for adoption, even when firms are expanding rapidly. Non-corroboration of H4 (on the relative advantage of the technology) is possibly the most surprising outcome of the quantitative analysis. Observing Figure 6.16 it is apparent that the majority of respondents saw, to a varying extent, some net benefit from the adoption of an IEPC, however this perception was hardly correlated with their adoption decisions (except for *reladv* = 5). The above, coupled with the rejection of H12 (on the technology's cost) point to the influence of non-pecuniary factors.

The rejection of hypotheses relating to the qualities of the technology (H14, H16, H17, H18 - *complx*, *compbl*, *obsrv*, *trial*) may be an indication of the implications of the uneven diffusion of information regarding the technology in question. It is also possible though that their absence of influence may stem, at least in part, from the pragmatic difficulties in quantifying such concepts and distinguishing them from other factors. Finally, hypotheses relating to the qualitative aspects of MNE linkages (dummies resulting from the categorical variable *mnelnk*) were not found to have a significant impact on the adoption decision. Though the fitted model illustrates that collectively, MNE linkages have an important effect on the decision to adopt, no single form of linkage (R&D/HRD co-operation, demand-pull or supply-push) was individually significant. It is probable that this result is a consequence of the small number of observations regarding each constituent part of the *mnelnk* variable.

6.7 Conclusion

Chapter 6 established in a systematic and methodical manner the determinants of adoption in a Greek SME sample. Initial correlation statistics provided cautious leads as to the underlying relationships. The logit model and its resulting odds provided a clear understanding of the relative importance of each determinant. To this effect, it corroborated a set of hypotheses made earlier (on Chapter 5). In addition, the surveyed SME sample provided a tentative indication as to the behaviour of Greek SMEs in general and confirmed some of the assumptions made earlier. Combined with the experience of the Greek economic reality amassed in Chapter 4, the findings of the empirical part are in a position to contribute to useful policy proposals.

Chapter 7 - Implications for Policy

7.1 Introduction

A common conclusion to the observation, analysis and interpretation of economic relationships is the provision of practicable recommendations for policy makers. Policy recommendations, some more obvious than others, follow and are informed by both the secondary and empirical findings. Due to the extremely narrow focus demanded by the present research thesis, any conclusions drawn are naturally not applicable in all relevant policy areas. This is why, policy recommendations should be made cautiously and should be context-specific. It should also be stressed that any suggestions made ought to be *realisable*; at the very least a short reference to relevant policy actors/institutions and their capabilities is to be made.

7.2 A "Blueprint" for Technological Competency

Diffusion theory can contribute to more than an explanation for the spread of individual technologies. The study of diffusion patterns and adopter decision making is essentially synonymous to that of social technological "receptiveness". Different social contexts have been found to have varied levels of technological receptiveness. Given a technology with identical characteristics throughout, being available simultaneously in different environments, the diffusion experience in each respective environment will differ. Tractors, electricity and telephone lines have had significantly different diffusion experiences among countries with comparable economic conditions. Despite one's inability to accurately quantify receptiveness there can be little doubt about the existence of such a measure. Perhaps an idea would be to view receptiveness in *relative* terms and make constructive comparisons across time and geographical (regions, countries, groups of countries) or economic (firms, industries, sectors) entities. This is where empirical surveys on diffusion, such as the one performed as part of this thesis, are especially useful; providing vital clues as to the degree of receptiveness.

Provided that technology is not just important for its obvious short-term qualities but systems for its creation and dispersal are the main value-adding mechanisms of modern economies (Lundvall, 1992), one can only wonder whether policy involvement could have an effect on this relative perceptiveness. Arguably, the study of diffusion can assist the compilation of a comprehensive '*blueprint for technological competency*'[129].

Classifying the factors influencing such decisions, either as facilitators or inhibitors is a first step. Economic factors have certainly proved important, but diffusion theory suggests a broader set of strategic, behavioural and even cultural influences on the decision to adopt any given technology. Policy can focus on manipulating these factors through financial, regulatory and institutional responses.

As shown in the empirical part, policy responses should cater for both changes in perceptions as well as real change in firms. 'Real change' would involve change in

[129] As explained later, such a 'diffusion-centred approach' to policy is not portrayed as panacea for technological competency; the author is very much aware of the study's limitations, particularly with regards to other stages of the innovation process (e.g. invention, original product development).

core economic sizes and relationships while changes in perceptions would involve changes in the views that firms have towards technology and ultimately towards risk and continuous change. While almost inevitably, (given enough time) perceptions follow reality, the logical distinction is still useful in devising measures with more immediate effects.

Past experience from the Greek environment has highlighted the necessity for such responses to be both *proportional* to the need which calls for them and *relevant* to the intended context. This is why case studies aiming to measure the relative weights of diffusion determinants are so important. The present thesis presented the methodological development of such a case-study; the present section attempts to utilise its findings to come up with realisable policy proposals. A special emphasis is placed on these proposals being realistic; a critical view of conventional policy responses is taken. The economic conditions, the structural form of the Greek economy and its institutional framework are taken into account. This is done so as to ensure the relevance of any propositions to the current environment. Where possible, the applicability of policy proposals and their outcomes are also elaborated.

7.2.1 Implications for Greek Technology Policy

Over the past few years, economic policy in Greece has been primarily concerned with sectoral restructuring and meeting the conditions for EMU entry. Worryingly, prior to EMU entry there had been a silent assumption that the fiscal stringency and monetary stability brought about by such policies would, somehow, result into increased competitive dynamism for Greek industry.

While there have been conscious efforts to change the nature of business organisations and the industries they operate in, little has been done to influence their productive capacity and internal operations. This is recognised in a survey of Greek entrepreneurship by IOBE (2004) which points at the severe competitive inadequacies of Greek firms. Citing structural, social and even cultural causes, IOBE (2004) draws a bleak picture of entrepreneurship in the Greek private firm sector and singles out SMEs as particularly ill-equipped to meet the demands of the modern business environment. In IOBE's analysis, the fact that Greek firms are essentially technological laggards, both with regards to diffusion and original innovation is treated as just another symptom of the overall condition. In the author's view such an interpretation is misplaced.

Technological retardness is much more than a mere manifestation of economic problems; in the modern networked business world it is, arguably, their very cause. As seen in Chapter 4, Greece is still at an early stage in harnessing the opportunities presented by modern ICTs. The restructuring effects of modern technologies are vastly underestimated at present, in the same way the economic potential of ICTs was overestimated in the pre-2000 dotcom boom. Indeed, perceptions as to the importance of technology matter for policy makers, just as they do for managers. The effects of the introduction of technologies though are very much real. Their introduction could contribute a lot to closing the competitive gap between domestic firms and foreign multinationals. Sustaining innovative activity both inside the firm and in its social and business environment is the solution to the problem of achieving international competitiveness and improving local entrepreneurship. In the medium term it could contribute to sustained growth and help meet the vision of economic convergence with developed Western economies. The gravity of the situation calls for substantial involvement by the government and other policy actors.

For such involvement to be successful it is necessary to divert policy away from simplistic, indiscriminatory, input-centred approaches and move towards a philosophy focusing on:

- Providing *targeted* support and incentives;
- Raising awareness regarding the *uses* of new technologies;
- Inducing the development of *systemic* interactions;
- Providing technological investment *advice*.

Policy aiming to change real economic characteristics, evidence suggests (Chapter 6), should focus on making financial capital available. The analysis of Greek diffusion experience in firms (Chapter 4) showed that many Greek firms are essentially opportunity adopters; they are largely indifferent to technological options until dramatically changing circumstances (usually financial intervention and/or the influence of market forces) attract their attention. Indeed, the empirical part of the project (Chapters 5&6) was partly motivated by the need to establish the current importance of finance on the decision to adopt. The Ministry of Development's "Go-

Online" programme treats the cost of technology as the main inhibitor; however, the programme's failure to attract enough participants, in spite of financing up to 40 per cent of the adoption cost, would appear to suggest that Greek SMEs are not very responsive to financial incentives. The empirical part of the thesis (on the adoption of IEPCs by Greek SMEs) showed that the availability of financial capital is still among the major determinants of adoption, albeit not the most important one[130]. The empirical part also showed that the decision to adopt is a complicated one and is far from being simply cost driven. Strategic considerations are also important (perceived threat from competition) as is intrinsic firm behaviour (being dynamic, risk taker with previous experiences and having linkages with multinationals) and considerations about the technology's characteristics (with life expectancy bring particularly pertinent to the case of IT adoption). In other words, financial incentives can help diffusion but there is no deterministic relationship between the two.

Moreover, such an effect on diffusion is not guaranteed; financial assistance programmes need to be appropriately planned and tailored to the characteristics of the adopter set. Rank-based models point at the importance of a firm's characteristics in its propensity to adopt. Empirical results too support the view that the encouragement of diffusion of not-so-new technologies with proven relative advantages can still best be served by carefully targeted inputs. Greek publicly funded adoption schemes such as "Go-Online" have set very loose eligibility criteria for recipients of technology adoption related funding. The empirical results make for a strong case against a blanket approach to adoption subsidies. To an extent, the criteria to be set depend on

[130] In the empirical model, its influence comes second in order of importance, after the effect of successful previous experiences.

the policy maker's agenda and may even pose philosophical questions. At first view it appears logical that money would be better spent in ways that promote maximum diffusion. Under this scenario only potential adopters who are more likely to adopt should be subsidised; it would be wasteful to force a technology upon firms which are technological laggards. Such a scenario would only be desirable if induced adoption could be achieved at a faster rate than would have been possible autonomously. At the same time though, a question of opportunity arises, itself giving rise to an alternate scenario. Offering financial support towards the adoption of key technologies to laggard firms may actually provide opportunities for novel technical and entrepreneurial ideas to flourish and support the survival and growth of firms specialising in specific market segments. This is important for modern technologies which, in some industries, are essentially vital facilitators of business ultimately determining survival. Thus, public choice is upheld and competition is, in effect, fostered.

More generally, the government could play an indirect role to making financial capital more accessible to SMEs with innovative ideas. Manipulating interest rates has historically been the tool of choice employed by central monetary authorities to foster investment. Paradoxically, the falling interest rates of recent years may have done little to encourage investment in technology – indeed the empirical model showed that the availability of capital is still very much a valid consideration. Christensen (1992) points to the irrelevance of interest rates in the context of technological investment. Christensen's reasoning is that high-risk investment ventures are, as a rule, not forestalled by high interest rates, as they are motivated by high expectations of return. Conversely, Chistensen (1992) argues that the governing mechanisms of financial markets and more specifically borrower-lender relationships have a far great impact on the availability of financial capital. SME managers in Greece have traditionally being excluded from financial markets and are unlikely to have an established and stable relationship with lenders. The government could help SMEs by intermediating loan agreements. A coherent framework for assessing technology related investment plans could be set in place and relevant government bodies may then evaluate business proposals and act as guarantors issuing references in support of the investment for borrowing purposes. This framework could be modelled after the successful '*small firm loan guarantee*'[131] scheme already in place in the UK.

In addition, a balance needs to be struck between demand and supply. So far policy in Greece has catered mostly for the supply of innovations, often taking demand for granted. Logotech's (2001) survey singles out the lack of demand as a significant obstacle to the diffusion of important innovations for development. While finance for the purchase of equipment is simultaneously more easily available due to better macroeconomic conditions and government funding, few provisions have been made with regards to the demand-side of diffusion. Greek firms exhibit little demand for technology so increasing the technology's supply would do little to promote diffusion. Money could be better spent on the strengthening of systemic links and demand-encouraging measures such as awareness raising schemes and fostering

[131] The UK Department of Trade and Industry guarantees loans from banks and other financial institutions for small firms that have viable business proposals but who have tried and failed to get a conventional loan because of lack of security (http://www.dti.gov.uk/sflg/).

competition by means of liberalisation. Among them count attempts to alter the perceptions with regards to a technology's profitability (or other form of relative advantage) and attempts to facilitate the diffusion of information (improve technological scanning). Advertising and training seminars for IEPCs and e-commerce applications organised by "Go-Online" are examples of the former, while the web-based "innovation relay centre[132]" operated by the NGO "Praxis" is an example of the latter. The above are not systematic (since they are heavily dependent on the occasional availability of EU-framework funding) and hence their effects on stimulating demand are bound to be minimal. The shrinking profit margins, particularly of SMEs, also contributed to a depressed demand for technology. As pointed out by Liagouras, Zambarloukos and Constantelou (2004) such market mismatches can be attributed to the 'importation' of policy frameworks from the EU core economies, which bear little relationship to the Greek reality. In Chapter 4, it was demonstrated that most of Greece's EU partners have exhibited greater openness to the diffusion of key technologies. Considering the importance of previous experiences in influencing the adoption decision (as highlighted by the empirical model), it follows that a greater proportion of firms in the EU technological core countries had has a greater propensity to adopt *a priori*. Thus, reinforcing the view that the application of an EU-initiated technological adoption scheme may be inappropriate. Policy interventions and adjustments must be made that are appropriate to the Greek context and take into account its distinctiveness.

[132] Praxis' Hellenic Innovation Relay Centre (HIRC): A web-based database listing existing locally produced technologies and tenders for joint development or technology transfer among companies in Greece (http://www.hirc.gr). Praxis' IRC is one of the few genuinely innovative attempts to improve technological scanning and encourage innovation synergies. It was recently rated the 2nd most effective IRC service among 71 European centres (Flash.gr, 2004).

It is true that some of this lack of demand is appropriability related; i.e. firms do not want the technology because they genuinely do not need it. However, appropriability could hardly account for the substantial diffusion gap among Greece and many of its EU partners. A historical aversion towards new ideas (cultural factors) must therefore account at least in small part for such perceptions. Reversing this culture calls for systemic interventions in education. A culture that is conservative in ideas is the natural conclusion of an educational system that values mnemonic skills over creativity and originality. The notoriously inefficient universities are also known to promote memorisation over creative aptitude skills. In the author's view this appears to have an indirect effect on the development of such a technologically-averse culture. Improvements in the effectiveness of tertiary institutions are imperative; whether this could come about as the result of liberalisation or privatisation is a subject of further investigation. Immediate measures would include the introduction of methods to assess quality of research across universities and the creation of comparative efficiency ranking lists. Linking the educational content of degrees with pragmatic industry needs should also be a priority and may contribute to curbing the unemployment problem facing the highly-qualified[133].

Where possible, attempts should be made to reverse cultural perceptions with regards to risk taking and creativity. Creating high-profile national awards and generous

[133] Mokyr (1992) brings down the inability of ancient Graeco-Roman society to sustain continuous innovation to the then prevalent manning of productive professions with slaves. In a quote that could just as well hold true for modern Greek society he concludes that: "*In a society in which those who are educated do not work and those who work are not educated, the inarticulateness of the productive classes will thwart the diffusion and adoption of new technology in the unlikely event that it emerges*" (Mokyr, 1992: 175)

scholarships for new ideas in science, engineering and entrepreneurship would be one form of incentive aimed at stimulating creative fervour. Encouraging links between education and industry could also work some way in ensuring that training and research is market-driven. Such encouragement could take the form of private firms and the state jointly financing the training of talented graduates to take out research in areas that are topical to the interests of the industrial sponsors. Far from simply inducing a one-off education-industry linkage, such joint initiatives could foster long-term co-operation, promote the profile of universities and portray them as viable outlets for subcontracting research.

Interventions should not stop at formal education but should aim to promote original thought and raise awareness about the benefits of specific innovations across society in general. Bartzokas (2001) and Logotech (2001) state that trade fairs are the commonest source of technological knowledge for smaller Greek firms. Arguably, technology trade fairs can have a substantial effect on adoption; as technology suppliers demonstrate the technology, diffusion of information occurs. The state can support a greater number of technological fairs and exhibitions and provide advice through existing structures (e.g. relevant government ministries, NGOs and research spin-offs) encouraging the participation of SMEs.

However, the effect of increased observability is greater when the technology is new; the empirical survey results in Chapter 6 suggest that increased observability has no effect on the adoption of widely known technologies (such as IEPCs). So trade fairs with a high-tech theme may be deemed to have a greater effect on the firms' propensity to adopt. Policy actors should identify new technologies with 'killer application' potential for productivity and competitiveness and work towards ensuring that Greek firms are quick at adopting. Some recent examples of candidate Information and Communication Technologies include wireless networks (WiFi), internet telephony[134] (VoIP) and even instant messaging[135] (IM). Technologies such as the above present the prospect of giving rise to specialised market niches that agile SMEs are perfectly poised to take advantage of. This could lead to the emergence of highly specialised firms focusing on high-tech goods and services, in turn stimulating demand for highly skilled labour and adding to Greece's international competitive advantage.

Souitaris (2001) and Kastelli and Tsakanikas (2000) point out that very few small firms harness the knowledge of their employees. Emphasis needs to be placed on human resources as a source of technology by investing in lifelong learning and continuous vocational education. A possibility for policy action comes in the shape of tax breaks allocated to companies that promote staff training (both inside and outside the firm) and encourage their employees to take courses in local technological institutes and universities. This necessitates enhancing the universities' local community links (which are at present non-existent) and creating flexible degree and pre-degree programmes aimed at busy professionals. Perhaps the focus of such

[134] Internet telephony (voice over internet protocol, i.e. VoIP) promises to nullify the cost of phonecalls by carrying digitised voice signals over existing internet infrastructure. The current convergence of WiFi (wireless networking) and VoIP technologies could have a great impact on the telecoms sector. Mobile telephony would be one of the more obvious uses of the new technology; the application of peer to peer communication protocols should permit free phonecalls within geographical areas with a sufficient user density (e.g. cities).

[135] HSBC Bank in the UK already offers online customer support, sales and advice by means of instant messaging. Such non-invasive and direct forms of communication hold great potential for increasing customer satisfaction while reducing support overheads.

schemes should be on skills that bear the greatest relevance to the current and future needs of the Greek economy.

Technology policy that aims to achieve a balance between the supply and the demand for technology should be based on accurate information regarding current diffusion levels both across firms (inter-firm) and within the firm (intra-firm). There is an urgent need for systematic collection and dissemination of relevant diffusion data. Currently there is an almost complete absence of diffusion-related statistics (Chapter 4). The existing innovation statistics in general are fragmented, disparate and scattered across numerous organisations. Ideally, a single responsible policy co-ordinator should be in charge of funding, monitoring and increasing the technological competency of all elements of the innovation system.

The GSRT should take responsibility for both primary data collection and secondary data gathering from various sources. It should cover all the lateral stages of the innovation process (basic science and R&D, technology transfer, diffusion and use of technology). A primary concern should be the collection of data on the diffusion of 'benchmark' technologies (general purpose technologies which could act as indicators of general trends) in industry, both at the inter-firm and the intra-firm level. The GSRT can also ensure that vital international technology transfer statistics, such as the TBP, are also accounted. A central innovation-related statistics repository would enable serious country-specific academic research and result in informed and therefore effective policy.

Even more than generic diffusion levels the provision of detailed information on specific adoption behaviour is valuable at pointing at specific deficiencies. As shown in Chapter 4, most small firms are 'product adopters'; they invest on technological products and, as a rule, ignore process technologies. Given the importance of process technologies in generating cumulative rises in productivity, this may be unfortunate for their international competitiveness. Additionally to being an important behavioural weakness at the firm level, the prevalence of the aversion towards process technologies in the economy in general translates into a slower pace of economic growth. Inducing the diffusion of process technologies should be treated as a matter a great priority. Financial and other incentives as well as particular measures that enhance the diffusion of information about process technologies are the obvious steps. Importantly the current mismatches between demand and supply in the labour market need to be addressed. There is a good chance that apart from being uninformed about such technologies Greek firms feel they do not need them as the availability of cheap labour, even highly skilled[136], acts as a substitute.

A large proportion of SMEs investigated postponed adoption until relatively late. It would be safe to assume that they are opportunity adopters as they only adopted when better financial conditions and the benefits of networking presented themselves. Knowledge of this behavioural trait and the proportion of the population which accounts for it are of great interest to technology policy. Significantly it helps single out those firms which are essentially averse to any form of technological adoption and can thus assist in devising a realistic potential adopter set when formulating

[136] Highly skilled the Greek labour force may be but, as discussed in Chapter 4, there is evidence to suggest that it is equipped with the 'wrong' skills.

relevant policy schemes. Additionally, identifying what these opportunities are perceived to be could ease the task of informing firms so as to ensure that their perceptions mirror the actual state of affairs as closely as possible. For example their perceptions with regards to the level of concentration in their sector and consequently the amount of competition they face have been shown empirically to have a great effect on a SME's decision to adopt (Chapter 6). Government policy attempting to inform businesses about the competitive pressure through, for instance, regular Herfindahl Index-based[137] bulletins on competition across industrial sectors would provide an invaluable tool for technological decision making. While this would be less meaningful in geographically constrained or otherwise saturated markets, it is bound to have a profound effect elsewhere. This is because competitive pressure increases the impetus for effective differentiation and thus increases the appeal of technological adoption in the short term and innovation in the longer term. Indeed, in the words of Joseph Schumpeter;

> *"[...] competition [...] acts not only when in being but also when it is merely an ever-present threat. It disciplines before it attacks."* (Schumpeter, 1942:85).

Such 'discipline' can only occur when adequate information is available and is disseminated effectively, a role that the National Statistics Service of Greece should certainly play.

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[137] The Herfindahl index is a measure of the size of the firms in relationship to the industry and an indicator of the amount of competition among them. Typically is it looks like: $HI = a^2 + b^2 + c^2 + \ldots n^2$ where a,b,c…n are the marker shares (%) of respective companies comprising an industry. It can take values ranging from 0 (highly competitive) to 10,000 (absolute monopoly).

Specific to diffusion, policy should actively support the development and timely spread of industrial standard technologies. As seen in Chapter 2, apart from the networking benefits arising from compatibility when everyone uses the same technology, such technologies are more likely to exhibit economies of scale in their production costs. Ultimately, industrial standard technologies have the greatest chances of widespread diffusion as the multiplicity of suppliers ensures not only reduced implementation costs but also helps in the diffusion of information (through increased observability). There is a need for standardisation policies to aim at more than simply fostering homogeneity; greater social benefit would result from their support for the diffusion of industrial standards of obvious merit. In the Greek case, the Hellenic Organisation for Standardisation (ELOT) has taken on the responsibility to codify and observe national standards in manufacturing, telecommunication and every other technical area requiring typification. It is the author's proposition that the knowledge and experience of ELOT could be well suited in identifying and promoting potential industrial standard technologies and that its role be expanded to accommodate the diffusion needs of the Greek economy. ELOT could be charged with the task of appraising internationally available industrial standards for transfer to the Greek environment. The organisation's partial and nevertheless successful involvement[138] in the "Adapt Initiative" shows that it is certainly capable of such undertakings.

[138] For further details see http://www.elot.gr

The spread of international industry standards in Greece will be a development that ultimately supports the emergence of local suppliers; as industrial standard technologies face no patent and royalty barriers their local production with minimal adjustments is a possibility. Attention should therefore be paid at promoting those industrial standards that are permissive of the technology's duplication and local development and production. A demonstratory example of the potential of technological standards comes from the software industry. Publicly available software innovations, known as 'open-source' software[139] are not only free to obtain for end use but are also not prevented from being copied, reverse-engineered and used, wholly or in parts, in the development of new commercial products and services. Numerous governmental bodies around the world[140] have adopted open-source software packages motivated firstly by the desire to reduce costs and secondly by security concerns[141]. Inevitably, the actual application and adjustments of these software applications to meet the requirements of government use are bound to fuel localised R&D in IT and thus maintain indigenous software industries. It would therefore be logical for the Greek government to embrace open-source software and take the first step in its promotion in Greece by adopting it itself. The cost of purchase of proprietary software could be rerouted to government-funded R&D

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[139] 'Open-source' is a generic term referring to software which: (a) is freely available to consumers as an end-product (b) its developers agree to publicise its source code (i.e. its component instructions and commands) so as to encourage further development and collaboration (c) its ownership status is governed by a license such as GPL (General Public License, issued by the Free Software Foundation - for details see http://www.fsf.org).

[140] Brazil and China have initiated large scale replacement of proprietary software used in government PCs in favour of open-source solutions. Several municipalities in Germany and France are testing the feasibility of such options (Cnet.com, 2001).

[141] The government of China for example is uneasy with the notion of trusting its administrative services to software developed wholly abroad by developers who are unwilling to allow it access to the software's source code. At the same time, most internet-spreading security threats such as viruses are aimed at proprietary systems (e.g. Microsoft Windows) as opposed to open source alternatives (e.g. Linux, FreeBSD etc.).

contracts allocated to private IT firms who undertake to adjust existing open source applications for government use. A large scale government adoption of open source software would have pervasive effects in the economy as a whole; due to the networking and complementarity features of open source software it would reduce the adoption cost of ICT for firms nationally; it would promote the accumulation of local knowledge and the strengthening of IT skills; it would advance the idea of the gift-economy (Bergquist and Ljungberg, 2001) favouring networking among ICT firms and leading to increased reciprocal collaborations.

A lot could be done to encourage cooperation among the enterprise sector, research institutions and universities; Lundvall (1992) and Edquist (1997) suggest that overall innovative competitiveness can be achieved when such systemic links among innovation actors are allowed to flourish. Lundvall (1992) argues that innovation is simultaneously more likely to happen and more likely to meet the needs of the market when it is the result of co-operation among different elements of the innovation system. Lundvall points to the importance of user-producer relationships when arguing in favour of R&D co-operation between industry and academia. Importantly, Lundvall argues, systemic co-operation makes actors susceptible to interactive learning; this accumulation of knowledge encourages the creation of social norms such as mutual trust and a capacity for further communication and networking.

Ideally, Greek technology policy should aim for the development of a 'national innovation system' (Edquist, 1997) where links between the firms (local and foreign, small and large), education, research and public sector actors lead to greater openness to new ideas, facilitate the diffusion of information and provide leads informing R&D and leading to increased and relevant innovation output. Linkages and occasional co-operation among actors will not alone result in the emergence of a coherent system. Policy makers can play a pivotal role in co-ordinating the direction of such linkages by means of incentives and ensuring that disparate, seemingly unconnected organisations are harmoniously working towards the same aim; that of increasing the economy's capacity to assimilate ideas and work towards creating new ones.

One systemic linkage which is of particular significance is the one existing among foreign and indigenous firms. MNEs can act as conduits for the international transfer of knowledge; they are by definition efficient at assimilating existing innovations, especially since they are exposed to international competition and are increasingly motivated by technological opportunism (Ethier and Markusen, 1991). The importance of linkages with MNEs has been discussed extensively in literature both at the theoretical and the empirical level. MNEs can facilitate the diffusion of technology in host countries through vertical market transactions (i.e. a local firm which is either a supplier or purchaser to an MNE is due to experience demand-pull/supply-push pressure to catch up technologically), through human resource spillovers and even by setting overall higher standards for the industries they operate in. Linkages with MNEs were empirically shown to be of relevance in the diffusion of IEPCs in Chapter 6, albeit with a small effect on the overall probability of adoption. The author suspects that this has more to do with the relatively small sample used (lack of observations regarding the particular factor) rather than the true relative weight of being associated with an MNE. Further research could establish this. The earlier experiences of the Asian 'Tiger' economies as well as the contemporary success of the economy of Ireland show that widespread MNE linkages are not only conductors for diffusion and innovation but also catalysts for broader economic development.

Policy actors should seek ways to introduce financial and other incentives for joint ventures and provide active support before, during and after the implementation of joint projects. The author proposes that this could be achieved through the establishment of 'business innovation centres' – physical government-funded entities where entrepreneurs can seek advice on the suitability of technology (with an emphasis on organisational innovations), engaging in joint ventures with foreign affiliates (whether innovation-related or otherwise) and novel business plans. The example of the UK and the services offered by the numerous 'Business Link' offices is a prospective platform to be considered. More generally, legislation amendments could be introduced that streamline the establishment of production facilities and encourage co-operation with local SMEs. The possibility of making adjustments to Greece's current tax regime regarding foreign affiliates is also one that may be worth considering. MNEs could in the long run prove central to absorbing Greece's highly qualified labour force and stimulate further demand for it. The sustainability of innovation-related FDI flows could in the long run help promote Greece as a regional innovation hub for the Balkans, South Eastern Europe and the Middle East.

Larger firms are certainly not less important than SMEs in creating employment and contributing to the economy's growth. Excessive policy focus on SMEs may divert attention from the fact that it is larger firms that can afford to sustain continuous R&D and thus provide the greatest possibilities for original innovation. Larger firms are also more likely to operate internationally and promote the internationalisation of the Greek economy (Kamaras, 2001). In being the primary actors of outward FDI, larger Greek firms act as conduits from the international transfer of technology. Despite the adverse circumstances, in recent years a small number of hi-tech companies have reached a scale that permits them to compete internationally[142]. Concrete measures for supporting them and using them as vehicles for the further development of hi-tech sectors need to be taken. The nature of such measures should be the focus of a dedicated industrial policy study but the immediate priority would be to diverge from popular perceptions about the 'malevolent'[143] predisposition of larger organisations and move towards one that is permissive of government support.

Finally, it is vital that existing structures are quickly adjusted to accommodate technological change. Industrial restructuring and the introduction of new innovations mean that new skills are bound to be needed and infrastructure will need to be upgraded. The swiftness of policy responses is often determined by the efficiency of public sector mechanisms. This implies that a streamlining of the currently massive, inefficient and corrupt public sector apparatus is a prerequisite.

The government need not always be the primary actor at inducing change; perhaps the greatest priority in technology policy in Greece at present is at creating an overall

[142] Companies such as Intracom (electronics), Intrasoft (software), Altec (computer hardware) and Inform (software).
[143] The origin of this perception can be traced back to Greece's socialist heritage.

environment that does not prevent *market forces* from promoting diffusion and innovation *themselves*. A fertile environment for innovation and diffusion involves, above all else, removing obstructions as are present in education and infrastructure. This is a difficult process that necessitates continuity in planning and an ability to learn from past mistakes; qualities that have so far been lacking from Greek technology policy. Once this has been achieved and the current obstacles have been removed, a more pro-active government role, involving a mixture of incentives and encouragement of systemic synergies can ensure that the average Greek firm is transformed from an awkward technological laggard, into a productive and flexible innovator. At this later stage the government must play an active role in maintaining an environment that is conducive to such changes, through continuous monitoring, evaluation and if necessary, adjustment.

7.2.1 Technology Policy Implications for Emerging Economies

Many of the policy implications for Greece can have wider applicability. SMEs are a common form of entrepreneurial organisation in countries which share similar developmental paths with Greece. These would include the EU's other cohesion countries (Portugal, Spain and to a lesser extent, Ireland) as well as Italy. Insights may also be of value to new EU accession and acceding members. Such countries could benefit from technology policies that are tailored to their respective macroeconomies, competition regimes, institutional frameworks, industrial structures as well as the *historical evolution* of the above elements.

An important lesson emanating from the study of technological diffusion in Greece is that the workings of the process are moulded dramatically by contextual factors. This is perhaps the single most important insight, in that it carries with it an implicit need for context-specific responses. Just as in other areas of economics, the past is in many cases a good predictor of the future. A national economy's evolutionary path dictates the structure and magnitude of many diffusion determinants, including industrial concentration, the availability of finance, relative prices, sectoral bias and even its cultural baggage.

A first priority should be putting in place instruments for the collection of data in topical policy areas. A technology policy should be guided by regular and systematic data collection exercises is more likely to be correct in its normative assumptions. The existence of comprehensive data on the adoption of technological goods and the generation of ideas makes for useful benchmarks to evaluate policy against. The need of policy benchmarking is arguably even more profound in emerging economies with a nascent institutional framework, where ample opportunities for rent-seeking may arise. Path-dependence may often mean that simply customising a policy response is not enough; the irreversibility associated with being 'locked' (Margolis and Liebowitz, 1995) within an evolutionary path means that totally original responses, yielding original, yet desirable outcomes are needed. An informed prescriptive policy could then embark on identifying *technological opportunities* and work towards aligning related *economic incentives*. Technology exhibits varying yields in different contexts (Canepa and Stoneman, 2002); the early identification and support of technology platforms with significant context-specific benefits on productivity and resource allocation may now be central to achieving national competitiveness.

7.3 Strategic Propositions for the Firm

Naturally, with the focus of the study being the enterprise sector in general, the findings bear greater relevance to industrial and innovation policy than they do to individual firm strategy. Research into intra-firm diffusion (the level of assimilation of a technology within the firm) would arguably be better suited to produce recommendations concerning not only strategy but also internal organisational structure. Nevertheless the present study is still in a position to provide some tentative strategic propositions at the firm level; insights from the adoption of IEPCs in Greek SMEs could be useful both for the demand side (investment in and management of technology) and the supply side (marketing of technology). This section translates empirical findings into realisable propositions for managers aiming at achieving "*technological adoption competency*"; i.e. how to transform the firm that will enhance its posture in adopting technologies, ideally adopting new innovations before competitors.

In the author's view, a firm can achieve this by enhancing its technological scanning activities. A first step to this direction would be to tap into the knowledge of staff and encourage employees to keep themselves informed about technological developments. This is admittedly difficult for SMEs where there is rarely the luxury of a large human capital base or a highly skilled one. However, even smaller firms can ensure that they attend trade fairs and are kept informed about technologies used by suppliers, customers and even competitors. Missing on a crucial upgrade could signify the firm's exclusion from an important market or its inability to provide a given good or service. It is therefore vital that firm managers constantly explore the technological possibilities for either forward or backwards vertical integration in operations. The adoption of an edge technology by a competitor could also position the firm at a competitive disadvantage. Naturally, a constant search must be in place to identify those technologies that offer possibilities for further cost-cutting and effective differentiation from competition.

It now seems that prior to taking a decision on whether to adopt or not, it is a good idea to experience the technology's qualities in operation, preferably in a company with the same field of operations. Partial adoption in a pilot trial prior to full scale roll out could also be beneficial. Diffusion theory tells us that trying a technology in its intended operational context prior to adoption can have a substantial effect in alleviating fear and ensuring the technology is appropriate. Where substantial investment is at stake, it is important to try different options and seek advice from expert consultants.

Moreover, a firm manager should use technology to further the reach of the company's products and services; modern ICT technologies are uniquely placed for such a purpose. SMEs are forced out of traditional markets and made to specialise even further on their specific niches. This increased specialisation represents an enormous competitive advantage that can be harnessed through ICT. Electronic commerce applications through web-based shops can broaden the firm's audience and guarantee its sustainability. Importantly, it has now become apparent that acquaintance with technological developments is just as important for company managers, as is an understanding of the business operations and market forces.

Finally, the findings of the present piece of research also have an implication for suppliers of technology and indeed technology marketers. The prevalence of previous successful experiences as the most significant factor in the sample studied hints at which firms to target. Past adopters are more likely to invest in IT again and a successful marketing strategy could begin by making reference to past, familiar applications of the technology, while demonstrating how the new product improves upon them. The relevance of the technology's life expectancy in the decision making process (Chapter 6) indicates that potential adopters are aware of the technology's complicated set of characteristics and the dynamics of the technology substitution process and therefore do not just arrive at their decisions by means of a simple cost-benefit analysis. Effective technology marketing for products with such short life expectancies as found in ICT could speed up technology investment decisions by informing potential adopters about the technology's expected life-cycle.

7.4 Conclusion

The present chapter presented a set of policy suggestions for Greece and elaborated on the implications of the research findings for other emerging economies. The author also briefly discussed implications at the firm level. In summary, corrective policy that aims to promote the assimilation of useful innovations should manifest concurrently on multiple fronts; industrial policy, education, innovation awareness and perceptions. Policy interventions should be context specific; avoiding 'one-fits-all' approaches should be a concern both at the micro and macro levels.

Chapter 8 - Concluding Remarks

8.1 Further Research

During the course of the study, it became obvious that numerous areas show great promise for further research. In particular, the creation of a technological map of Greece and the empirical part identified a multitude of potential research leads which have been impossible to adequately explore in the present work. The intense focus demanded by the objectives of thesis coupled with the resource restrictions associated with it inevitably meant that only topics of immediate interest have been looked at. Difficult choices had to be made in focusing on areas that hold not only great academic interest but are of topical interest for the purposes of diffusion policy and technology management alike. It is inevitable that many more important questions remain unanswered. This presents a valuable opportunity for future research in the field.

The contribution of the present work was primarily on the empirical sphere. Nevertheless, the literature review of existing theoretical approaches to diffusion highlighted areas where existing theory falls short of providing adequate explanations. There is for example little accounting for the risk-taking behaviour of some firms, apart from that they must perceive benefits and risks in substantially different ways. The family of rational choice models could be informed in the future by approaches derived from other behavioural sciences.

Very little economic work has been done on the importance of interpersonal networks; an area which has been traditionally the realm of sociologists but one that is gaining ground in economics through the study of clusters and employing tools such as network analysis. Future research employing network analysis could assist both in conceptualising the form and measuring the intensity of linkages among innovation actors. Importantly, it could account for factors leading to strong co-operative relationships and their geographic density. Another research avenue identified in due process has to do with methodological aspects of modelling and measuring diffusion, namely with the application and effectiveness of new research instruments in surveying and dissemination. The surveying process could receive a significant boost in efficiency through employing web-based surveys. The resulting datasets, confidentiality considerations permitting, could then be effectively disseminated by means of a modular, web-based database.

In terms of empirical research, there are currently no studies modelling intra-firm diffusion in Greece. Technology adoption is a useful starting point, but the effective use and the proportion of output that a technology accounts for are necessary for a more holistic understanding of the impact of technology in the production process. Further research could explicitly look into intra-firm diffusion and produce insights that are useful for the inner workings of the firm. The influence of human resources on diffusion could also be modelled, resulting in concrete proposals for labour and education policy.

Finally, the interactions between the characteristics of technology, the diffusion environment and the adopters' characteristics have yet to be accurately modelled in a sufficiently large number of situations to enable one to produce informed predictions for a variety of scenarios. More research is called for in this area, which can have an immediate value for informing policy making decisions.

8.2 Conclusion

Diffusion theory has come a long way from the works of Griliches (1957) and Mansfield (1961). The conceptual models employed to interpret diffusion have evolved in diverse directions. Later works (Karshenas and Stoneman, 1995; Goel and Rich, 1997; Gourlay, 1998) attempt to bring distinct approaches together and incorporate epidemic, rank and evolutionary effects. Works on diffusion have largely either focused on the early lateral stages of diffusion (diffusion of information) or on the assimilation of technologies within the firm (intra-firm diffusion). The present study is one of few investigating the intermediate stage, where the decision on whether to adopt or not is taken. It is also together with Goel and Rich (1997), Kaufmann (1998), Bartoloni and Baussola (2001) and Courchance, Nickerson and Sullivan (2002) one of few utilising a logit model to establish the relative importance of determinant factors on the decision to adopt.

While in recent years important steps have been taken in the development of diffusion theory a respective volume of empirical work has not accompanied them. The present work contributes to the literature by putting such theories to the test; the empirical part largely corroborates ranked-based theories and the importance of systemic links.

It also introduces successful past experiences as an important determinant of adoption.

Importantly, the study proposes a diffusion-centred policy framework for technological competence. During the course of the thesis the author hinted at the importance of diffusion for productivity and growth. Diffusion is more than the spread of innovations; it is the very instrument by which knowledge spreads across society. The dissemination of new ideas, methods and even tangible product goods has a cumulative effect on factor endowments (Young, 1995). Countries that are successful at increasing their technological receptiveness embark on a path of sustainable growth. This is why diffusion should be central to economic planning and not confined to the fringes of the realm of industrial policy. Indeed, pervasive actions cutting across industry, education and public sector institutions are necessary to induce improvements in Greece's receptiveness of new ideas.

Without doubt, further study is called for in the area, as limitations associated with the present study did not permit an all-inclusive, holistic analysis of diffusion. There is value in replicating and extending the study's findings by means of a further, larger-scale empirical exercise. Such an exercise could give a conclusive verdict on the validity of hypotheses which have not been corroborated here.

The contribution of the present thesis on the body of academic knowledge in the field is not negligible. First of all, it is the only survey of its kind focusing on the Greek economy. In the past, there have been studies on Greek technological performance (e.g. Korres, 1995) but none placed due importance to the diffusion of innovations. The author has contributed an up to date account of Greek technological competencies linked to an overview of technology policy. The compilation of the 'technological map' of Greece combined with the findings of the empirical survey, provide a good indication as to the economy's overall level of receptiveness.

Secondly, the application of the logit model on the decision to adopt has yielded a useful way to ascertain the relative importance of diffusion determinants. The odds ratios employed aid our understanding and permit the easy communication of results across a variety of audiences. While the method itself is far from new, its application on perception-based modelling is certainly not common. The usage of perceptions enabled a direct insight into the decision making process, rather than the broader factors influencing it. The importance of successful previous experiences showed that one-off inputs (like spending on the adoption of ICT) can have very significant long term effects. Significantly, this means that ICT subsidies need not continue indefinitely; once a firm has adopted once, chances are that the positive experiences acquired with the technology serve to reverse the culture of averseness.

Thirdly, the author devised a new diffusion-oriented conceptual typology of technology. Far from being simply a purposeless end by itself, it was demonstrated that the typology is a useful tool in the analysis of observable diffusion trends. Indeed, elements of the typology facilitated the appraisal of Greek technological performance (Chapter 4), informed the construction of the survey (Chapter 5) and assisted the interpretation of both the unprocessed data and the econometric findings (Chapter 6).

Lastly, the study led to the identification of major deficiencies of the Greek innovation system. The apparent lack of demand for process technologies is closely linked to the status of the labour market. The ambiguous role of technology parks is in contrast with the positive influence of trade fairs on the diffusion of information. While studies (Kastelli and Tsakanikas, 2000; Logotech, 2001b) show that the number of co-operative research ventures is rising, there is no evidence yet that systemic links have resulted in increased technological performance. The major drawbacks of Greek technology policy have been the lack of long-term strategy enacted by a single organisational authority, the absence of extensive and reliable technology statistics to inform policy, an outdated educational philosophy and a reluctance to move away from generic one-fits-all approaches and move towards effective micromanagement.

The author provided numerous suggestions aimed to stimulate demand, promote diffusion and eventually lead to substantial levels of original value-adding innovation. With 'economic convergence' towards the EU average being high on the Greek government's agenda, closing the technology gap is certainly a prerequisite.

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Appendices

Appendix 1 – Questionnaire

[ENGLISH TRANSLATION]

northumbria
UNIVERSITY

Newcastle Business School
Division of Economics

Questionnaire

The present questionnaire forms part of my research into the economics of technology and more specifically the adoption of new technologies by small and medium entreprises (SMEs). [Ascertaining] The factors influencing the success of a technology in the Greek business environment is what I hope to achieve through this survey. The findings of the survey may be useful for the marketing of new technologies, for international comparisons for the formation of government policy supporting SMES as well as the reorganisation of businesses and the formation of structures that are friendly to new technologies.

I warmly thank you for your participation.

Dimitrios Pontikakis

INSTRUCTIONS:

The questionnaire should be completed by the manager of your company or alternatively someone with good knowledge of the company's activities and finances.
Please try to answer to all questions with as great accuracy as possible. If part of a question is not applicable to your company you may not answer it. Please return it to:

[author's postal address]

or if returning by email to:
[author's email]

DECLARATION OF CONFIDENTIALITY

By the current statement I agree to treat with strict confidentiality all information (details, data) provided in your answers to the questions that follow.
I reassure you that information will only be used for the purpose of statistical and econometric analysis forming part of my doctoral thesis for the University of Northumbria in Great Britain. I also assure you that in the case of publication of either primary data or processed results, no details or data that may identify your company is to be mentioned.

Dimitrios Pontikakis

15 July 2003

If you have any questions regarding the questionnaire, please contact me:

[Author's email]
[author's phone number]

Question 1.

Is your company independent?
(please tick √)

Yes	
No	

Question 2.

How many people work in your company?
(please tick √)

9 or less	
10-19	
20-49	
50-249	
250 or more	

Question 3.

What is your annual turnover?
(please tick √)

Less than €100,000	
€100,000 – €500,000	
€500,000 – €700,000	
€700,001 – €4,000,000	
More than €4,000,001	

Please report the turnover of the last two years.

Year 1	
Year 2	

Question 4.

How many years have you been operating?
(please tick √)

Less than 2	
2 – 5	
5 – 10	

10 - 20	
20 or more	

Question 5.

Please indicate the industry type that best describes the nature of your business. (please tick √)

Industry Type	**Tick (√)**
Manufacture	
Retail/Wholesale	
Communications/ IT	
Agriculture	
Transport	
Crafts	
Tourism	
Shipping	
Other (please describe)	

Question 6.

If you had invested in the period 1970-1989 in a computer do you consider that the relative yield (cost/performance) of the technology was positive (i.e. it was worthwhile) or negative (i.e. it was not worthwhile)?

Our company had not invested in such a technology during the period 1970-89	
Positive (our investment was worthwhile)	
Negative (our investment was not worthwhile)	

Question 7.

Do you use one or more ***computers with internet access*** in your company which were bought after 1990? If your answer is yes, please state the year at which you first introduced computers in your work environment.

No we do not use computers	
Yes we do use computers	We started in the year ....

If you answered NO to question 7, ignore questions 8 until 12 and carry on with question 13.

Question 8.

Computers have a variety of uses in a business context. Also as they evolve they acquire new abilities and have added business applications. What follows is a list of different application where computers can assist the running of the business. If you use a computer to cover your firm's needs in any of these areas please state which year you started doing so.

Application	**Year**	**Application**	**Year**
Customer Resource Management (CRM)		Accounting and Finance Software (invoicing)	
Inventory and Ordering Management Software		Graphics Editing / Desktop Publishing	
Internet Access (including web, email and other services)		Databases	
E-Commerce (business to consumer)		E-Business (business to business)	
Other (please state)		Other (please state)	

Question 9

In your opinion, how much did your company benefit from the implementation of these applications into its business structures? Please balance the benefit you feel your company has received against its original investment.

(rate 1 – 5, 1=very small benefit, 5 = very significant benefit)

Application	**Benefit (1 – 5)**				
Customer Resource Management (CRM)	O 1	O 2	O 3	O 4	O 5
Inventory and Ordering Management Software	O 1	O 2	O 3	O 4	O 5
Internet (including web, email and other services)	O 1	O 2	O 3	O 4	O 5
Accounting and Finance Software (invoicing)	O 1	O 2	O 3	O 4	O 5
Graphics Editing / Desktop Publishing	O 1	O 2	O 3	O 4	O 5
Databases	O 1	O 2	O 3	O 4	O 5
E-Commerce (business to consumer)	O 1	O 2	O 3	O 4	O 5
E-Business (business to business)	O 1	O 2	O 3	O 4	O 5
Other (please state)	O 1	O 2	O 3	O 4	O 5
Other (please state)	O 1	O 2	O 3	O 4	O 5

Question 10

If you have been using computers in your business for some time now, you have probably had to upgrade both hardware and software. When considering the purchase/implementation of new equipment or software how important is the life expectancy of the item?
(please rate from 1[= not important] to 5 [=very important])

Importance of life expectancy

O	O	O	O	O
1	2	3	4	5

Question 11

With respect to your competitors, how early or late did you incorporate computers in your business structure?

(please rate from 1[= very late] to 5 [=very early])
Late Adopter ← → Early Adopter

O	O	O	O	O
1	2	3	4	5

Question 12

Have you ever received government assistance (in the form of funding and/or training) connected with the use of computers or any other IT related technology?

(Please delete as appropriate)

Yes No

If your answer to the above was yes then please state what percentage of the assistance related to the investment total.

Percentage ....

Question 13

How easy (or difficult) is it to come up with the funds needed for the purchase of new technology?

(please rate from 1[= very difficult] to 5 [=very easy])
Finance not available ← → Finance available

O	O	O	O	O
1	2	3	4	5

Question 14

Does your firm cooperate in any stage of its operations with one or more multinational companies? Please state the level of cooperation in each one of the following areas:

Cooperation Type	(please rate from 1[= not at all] to 5 [=very much so])
Trading Partner	O O O O O 1 2 3 4 5
Your firm acts as a supplier for the multinational	O O O O O 1 2 3 4 5
Your firm **directly** purchases products or services provided by a multinational	O O O O O 1 2 3 4 5
Cooperation in research & development (including knowledge sharing)	O O O O O 1 2 3 4 5
Cooperation in employee training	O O O O O 1 2 3 4 5

Question 15

Would you describe the environment and the industry where your firm operates as competitive? Please state what you believe to be the level of competition in your business field. (please rate from 1[= very little competition] to 5 [=very high competition])

Not competitive ← → Highly competitive

O	O	O	O	O
1	2	3	4	5

Do you believe that this is due to:	(please rate from 1[= not at all] to 5 [=very much so])

The saturation of the business sector	O 1 / O 2 / O 3 / O 4 / O 5
The high rate of technological progress	O 1 / O 2 / O 3 / O 4 / O 5
Other factors (please state) Factor 1 .... Factor 2	 O 1 / O 2 / O 3 / O 4 / O 5 O 1 / O 2 / O 3 / O 4 / O 5

Question 16

To what extent did you find the incorporation of computers into your business operations to be a complex and time consuming process?

(please rate from 1[= not at all] to 5 [=very much so])
Adoption Complexity

O	O	O	O	O
1	2	3	4	5

Question 17

Prior to the purchase/implementation of computer related technology had you witnessed it operating in other firms?
(please tick √)

Yes	
No	

Question 18

Prior to the purchase/implementation of computer related technology were you given a chance to try the application?
(please tick √)

Yes	
No	

Question 19

To what extent was the technology adopted (both hardware and software) compatible with your business structures and ways of doing business in general.

(please rate from 1[= incompatible] to 5 [=highly compatible])
Compatibility

O	O	O	O	O
1	2	3	4	5

Question 20

Did you find that significant adjustments had to be made to your firm's existing structures, business habits and existing technologies in order to accommodate the adoption of computers? Please rate the extent of these adjustments.

(please rate from 1[= very few adjustments] to 5 [=significant changes])
Changes in business structure, technology

O	O	O	O	O
1	2	3	4	5

Question 21

If your company has access to the internet, what kind of connection does it utilise?

Type of Connection	(please tick √)
Traditional Phone Line (PSTN 56kbps)	
ISDN Phone Line (64/128 Kbps)	

xDSL Line	
Leased Line	
Other (please state)	

Question 22

If your company has or has accessed the internet through any of the above mentioned connections please state the year they were adopted.

Type of Connection	Year of Adoption
Traditional Phone Line (PSTN 56kbps)	
ISDN Phone Line (64/128 Kbps)	
xDSL Line	
Leased Line	
Other (please state)	

For example:

Type of Connection
Traditional Phone Lin (PSTN 56kbps)
ISDN Phone Lin (64/128 Kbps)
xDSL Line
Leased Line
Other (please state)

Question 23

In which areas do you believe that your business has improved its efficiency since the implementation of computers?

(please rate from 1[= no improvement] to 5 [=significant improvement])

Area of Business Operations	Degree of Improvement				
Inventory & ordering	O 1	O 2	O 3	O 4	O 5
Accounting & finance	O 1	O 2	O 3	O 4	O 5
Information bases	O 1	O 2	O 3	O 4	O 5

Marketing	O 1	O 2	O 3	O 4	O 5
Customer services, relations & support	O 1	O 2	O 3	O 4	O 5
Production	O 1	O 2	O 3	O 4	O 5
Decision making	O 1	O 2	O 3	O 4	O 5
Business networking	O 1	O 2	O 3	O 4	O 5
Human resources	O 1	O 2	O 3	O 4	O 5

QUESTIONNAIRE END.

ORIGINAL IN GREEK FOLLOWS

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Ερωτηματολόγιο

Το παρόν ερωτηματολόγιο αποτελεί μέρος της έρευνας μου στα οικονομικά της τεχνολογίας και συγκεκριμένα την υιοθέτηση νέων τεχνολογιών από τις μικρομεσαίες επιχειρήσεις (ΜΜΕ). Μέσα από αυτή την έρευνα προσπαθώ να εντοπίσω ποιοι παράγοντες (οικονομικοί και μη) καθορίζουν την επιτυχία μιας τεχνολογίας στο ελληνικό επιχειρηματικό περιβάλλον. Τα ευρήματα αυτής της έρευνας μπορούν να φανούν χρήσιμα για το μάρκετινγκ τεχνολογιών, για διεθνείς συγκρίσεις, για τον σχηματισμό κυβερνητικής πολιτικής για την υποστήριξη των ΜΜΕ αλλά και για την αναδιάρθρωση επιχειρήσεων και τον σχηματισμό δομών φιλικών προς νέες τεχνολογίες.

Σας ευχαριστώ θερμά για την συμμετοχή σας.

Δημήτριος Ποντικάκης

ΟΔΗΓΙΕΣ:

Το ερωτηματολόγιο θα ήταν καλό να το συμπληρώσει ο διευθυντής ή η διευθύντρια της εταιρείας σας, ή οποιοσδήποτε γνωρίζει με ακρίβεια τις δραστηριότητες και τα οικονομικά μεγέθη της.
Προσπαθήστε να απαντήσετε σε όλες τις ερωτήσεις όσο το δυνατόν με μεγαλύτερη ακρίβεια. Αν κάποιο σκέλος μιας ερώτησης δεν σας αφορά αφήστε το αναπάντητο. Παρακαλώ επιστρέψτε το στο:

[author's postal address]
ή μέσω email στο:
[author's email]

<u>ΔΗΛΩΣΗ ΠΡΟΣΤΑΣΙΑΣ ΔΕΔΟΜΕΝΩΝ</u>

Με την παρούσα δήλωση, δεσμεύομαι να τηρήσω απόλυτη εχεμύθεια για όλες τις πληροφορίες (στοιχεία, δεδομένα) που μου παρέχετε στις ερωτήσεις που ακολουθούν.
Σας διαβεβαιώνω ότι θα χρησιμοποιηθούν μόνο για τον σκοπό της στατιστικής και οικονομετρικής ανάλυσης σαν μέρος της διδακτορικής διατριβής μου για το Πανεπιστήμιο της Νορθάμπρια στην Μεγάλη Βρετανία. Επίσης, σας διαβεβαιώνω ότι σε περίπτωση δημοσιοποίησης είτε πρωτογενών δεδομένων, είτε επεξεργασμένων αποτελεσμάτων, δεν θα αναφερθούν στοιχεία ή δεδομένα που θα μπορούσαν να οδηγήσουν στην αναγνώριση της εταιρείας σας.

Δημήτριος Ποντικάκης

15 Ιουλίου 2003

Αν έχετε ερωτήσεις σχετικά με ερωτηματολόγιο παρακαλώ επικοινωνήστε μαζί μου:

Ηλεκτρονική διεύθυνση: dimitrios.pontikakis@unn.ac.uk
Τηλέφωνο (Μεγάλη Βρετανία): 0044-7739-419793

Αν επιθυμείτε να λάβετε μια σύντομη αναφορά με τα ευρήματα της έρευνας και γενικές προτάσεις για την αποτελεσματικότερη κάλυψη των αναγκών σας από νέες τεχνολογίες παρακαλώ συμπληρώστε τα στοιχεία σας στο κενό που ακολουθεί.

<u>Ονομασία Επιχείρησης</u> ....
<u>Διεύθυνση</u> ....
....
....
<u>Τηλέφωνο</u> ....
<u>Ηλεκτρονική Διεύθυνση (e-mail)</u> ....

Ερώτηση 1.
Θεωρείτε ότι η εταιρεία σας είναι ***ανεξάρτητη***;
(παρακαλώ σημειώστε **X**)

Ναι	X
Όχι	

ΕΠΕΞΗΓΗΣΗ: Η εταιρεία σας θεωρείται ανεξάρτητη για τους σκοπούς της έρευνας μόνο εάν δεν ανήκει σε κάποιον συνεταιρισμό, ή δεν ελέγχεται με οποιονδήποτε τρόπο από κάποια μεγαλύτερη επιχειρηματική οντότητα (π.χ. μια πολυεθνική).

«X»

Ερώτηση 2.
Πόσα ***άτομα*** απασχολούνται στην επιχείρηση σας;
(παρακαλώ σημειώστε **X**)

10 ή λιγότερα	X
11-20	
21-50	
51-250	
251 ή περισσότερα	

(x2)

ΕΠΕΞΗΓΗΣΗ: Ο αριθμός των εργαζομένων που θα δηλώσετε πρέπει να περιλαμβάνει οποιονδήποτε ή οποιαδήποτε προσφέρει έργο για την επιχείρηση, ακόμα και αν δεν πληρώνεται, συμπεριλαμβανομένων εποχιακού προσωπικού και μελών της οικογένειας του ιδιοκτήτη-τριας.

Ερώτηση 3.
Πόσο είναι κατά μέσο όρο ο ετήσιος ***τζίρος*** σας;
(παρακαλώ σημειώστε **X**)

Λιγότερο από €100,000	
€100,001 - €500,000	
€500,001 - €700,000	
€700,001 - €4,000,000	
Περισσότερο από €4,000,001	

(x2)

ΕΠΕΞΗΓΗΣΗ: Αν είναι δυνατόν δηλώστε το μέγεθος του τελευταίου οικονομικού έτους, αλλιώς ένα μέσο ποσό των τελευταίων πέντε ετών επαρκεί. Η παρούσα κατηγοριοποίηση των ΜΜΕ με βάση το μέγεθος και τον τζίρο είναι σύμφωνη με τις υποδείξεις της Ευρωπαϊκής Ένωσης.

Παρακαλώ αναφέρετε τον τζίρο των δύο τελευταίων ετών.
(απόλυτο ποσό σε ευρώ)

Έτος 1	
Έτος 2	

(x4)

Ερώτηση 4.
Πόσα ***χρόνια*** δραστηριοποιείται η εταιρεία σας;
(παρακαλώ σημειώστε **X**)

Λιγότερα από 2	
3 - 5	
6 - 10	
11 - 20	
21 ή περισσότερα	

(x4)

Ερώτηση 5.
Παρακαλώ επιλέξτε τον ***τομέα*** στον οποίο δραστηριοποιείται η εταιρεία σας. (παρακαλώ σημειώστε **X**).

Τομέας	**Σημειώστε (X)**
Βιομηχανία/Βιοτεχνία	
Εμπόριο Λιανικής/Χονδρικής	
Επικοινωνίες/Πληροφορική	
Γεωργία	
Μεταφορές	
Χειροτεχνία	
Τουρισμός	
Ναυτιλιακά	
Άλλο (παρακαλώ περιγράψτε)	

ΕΠΕΞΗΓΗΣΗ:
Αν η εταιρεία σας δραστηριοποιείται σε περισσότερους από έναν τομείς, σημειώστε μόνο αυτόν στον οποίον επικεντρώνεται το μεγαλύτερο μέρος των δραστηριοτήτων σας.

Ερώτηση 6.
Αν είχατε επενδύσει κατά την περίοδο 1970-1989 σε ηλεκτρονικούς υπολογιστές (ή σε άλλη τεχνολογία αυτοματισμού ή/και πληροφορικής ή/και επικοινωνίας) θεωρείτε ότι το σχετικό όφελος (κόστους/απόδοσης) αυτής της τεχνολογίας ήταν **θετικό** («έπιασε τόπο») ή **αρνητικό** («δεν έπιασε τόπο»);

Η εταιρεία μας δεν είχε επενδύσει σε τέτοια τεχνολογία την περίοδο 1970-1989	
Θετικό (η επένδυση μας τότε «έπιασε τόπο»)	
Αρνητικό (η επένδυση μας τότε «δεν έπιασε τόπο»)	

Ερώτηση 7.

Χρησιμοποιείτε έναν ή περισσότερους ***ηλεκτρονικούς υπολογιστές με πρόσβαση στο διαδίκτυο (internet)*** στην επιχείρηση σας που αγοράστηκαν μετά το 1990; Εάν η απάντηση σας είναι ναι, παρακαλώ αναφέρετε το έτος κατά το οποίο χρησιμοποιήσατε ηλεκτρονικούς υπολογιστές στο περιβάλλον εργασίας σας για πρώτη φορά.

Όχι, δεν χρησιμοποιούμε ηλεκτρονικούς υπολογιστές		
Ναι, χρησιμοποιούμε ηλεκτρονικούς υπολογιστές.		Ξεκινήσαμε το έτος ....

Αν απαντήσατε ΟΧΙ στην ερώτηση 7, αγνοήστε τις ερωτήσεις 8 έως 12 και συνεχίστε απαντώντας την ερώτηση 13.

Ερώτηση 8.

Οι ηλεκτρονικοί υπολογιστές έχουν πληθώρα εφαρμογών σε μια επιχείρηση. Με το πέρασμα του χρόνου οι δυνατότητες τους γίνονται περισσότερες και μπορούν να βοηθήσουν σε ένα αυξανόμενο αριθμό εργασιών. Ακολουθεί ένας πίνακας με διάφορες ***εφαρμογές*** ηλεκτρονικών υπολογιστών που καλύπτουν ένα ευρύ φάσμα επιχειρηματικών και παραγωγικών αναγκών. Αν χρησιμοποιείτε ηλεκτρονικούς υπολογιστές σε οποιαδήποτε από τις παρακάτω εφαρμογές, παρακαλώ αναφέρετε το έτος κατά το οποίο ξεκινήσατε.

Εφαρμογή	**Έτος**	**Εφαρμογή**	**Έτος**
Διαχείριση Πελατών (CRM)		Λογιστική, Χρηματο-οικονομικά και Τιμολόγηση	
Διαχείριση αποθήκης, στοκ και παραγγελιών από προμηθευτές		Δημιουργία/επεξεργασία γραφικών, Επεξεργασία Κειμένων	
Πρόσβαση στο Διαδίκτυο (Internet)		Βάσεις Δεδομένων	
Ιστοσελίδα ηλεκτρονικού εμπορίου (για καταναλωτές)		Ιστοσελίδα ηλεκτρονικού εμπορίου (για επιχειρήσεις)	
Άλλο (παρακαλώ αναφέρετε)		Άλλο (παρακαλώ αναφέρετε)	

Ερώτηση 9.

Πόσο ήταν το κόστος της ολικής σας επένδυσης στην τεχνολογία. Παρακαλώ εκτιμήστε όχι μόνο τα έξοδα αγοράς αλλά και τα έξοδα εγκατάστασης, εκπαίδευσης και εξοικείωσης προσωπικού κ.α. (σε απόλυτο ποσό).

Κόστος σε ευρώ (μια εκτίμηση αρκεί)	....

Πόσο μεγάλο πιστεύετε ότι ήταν το κόστος σε σχέση με την ικανότητα της επιχείρησης σας να χρηματοδοτήσει την ενσωμάτωση της τεχνολογίας;

Μικρό κόστος ← → Μεγάλο κόστος

O	O	O	O	O
1	2	3	4	5

Κατά την γνώμη σας, πόσο επωφελήθηκε η επιχείρηση σας από την υιοθέτηση αυτών των εφαρμογών; Παρακαλώ προσπαθήστε στην απάντηση σας να αντισταθμίσετε το ***όφελος*** που πιστεύετε ότι είχε η εταιρεία σας σε σχέση με το μέγεθος της αρχικής επένδυσης στην συγκεκριμένη τεχνολογία.

(βαθμολογείστε από το 1[=μηδαμινό/αρνητικό όφελος] έως το 5[= πολύ σημαντικό όφελος])

Όφελος σε σχέση με επένδυση (1 – 5)

O	O	O	O	O
1	2	3	4	5

(x8)

Ερώτηση 10.

Αν χρησιμοποιείτε ηλεκτρονικούς υπολογιστές στην επιχείρηση σας για αρκετό καιρό, θα έχετε πιθανότατα αναγκαστεί να αναβαθμίσετε ή και να αντικαταστήσετε τον εξοπλισμό σας. Όλες οι τεχνολογίες έχουν ένα πεπερασμένο αναμενόμενο περιθώριο χρησιμότητας (*βιωσιμότητα*), είτε γιατί οι ανάγκες μιας επιχείρησης αλλάζουν είτε γιατί η εν λόγω τεχνολογία αντικαθίσταται από μια νεότερη. Όταν σκέφτεστε την αγορά/εγκατάσταση νέου εξοπλισμού ή λογισμικού, πόσο σημαντική είναι για την απόφαση σας η ***βιωσιμότητα*** της τεχνολογίας;

(βαθμολογείστε από το 1[=καθόλου σημαντικό] έως το 5[= πολύ σημαντικό])

Βιωσιμότητα

O O O O O
1 2 3 4 5

Ερώτηση 11.

Σε σύγκριση με τους ανταγωνιστές σας, πόσο ***νωρίς*** ή ***αργά*** ενσωματώσατε ηλεκτρονικούς υπολογιστές στην επιχείρηση σας;

(βαθμολογείστε από το 1[=πολύ αργά] έως το 5[= πολύ νωρίς])

Αργότερα ← → Νωρίτερα

O O O O O
1 2 3 4 5

Ερώτηση 12.

Έχετε λάβει ποτέ ***κυβερνητική/Ε.Ε. βοήθεια*** (με την μορφή χρηματικής επιδότησης ή παροχής εκπαίδευσης) για την υλοποίηση εφαρμογών ηλεκτρονικών υπολογιστών;
(παρακαλώ σημειώστε **X**)

Ναι	
Όχι	

Αν απαντήσατε ΝΑΙ στην παραπάνω ερώτηση και η βοήθεια είχε την μορφή χρηματικής επιδότησης, παρακαλώ αναφέρετε το ποσοστό που αντιστοιχούσε στην βοήθεια από το ολικό ποσό της επένδυσης σας για την υλοποίηση της τεχνολογίας.

Ποσοστό τοις εκατό ....%

Ερώτηση 13.

Πόσο εύκολο ή δύσκολο είναι να συγκεντρωθεί το αναγκαίο ***χρηματικό ποσό*** για την αγορά και ενσωμάτωση μιας νέας τεχνολογίας στις δομές μιας επιχείρησης; (π.χ. από επιδοτήσεις, δανεισμό ή εταιρικά κέρδη)

(βαθμολογείστε από το 1[=πολύ δύσκολο] έως το 5[= πολύ εύκολο])

Έλλειψη κεφαλαίου ← → Διαθεσιμότητα κεφαλαίου

O O O O O
1 2 3 4 5

Ερώτηση 14.

Συνεργάζεται η επιχείρηση σας σε οποιοδήποτε λειτουργικό της τομέα με μια ή περισσότερες ***πολυεθνικές*** επιχειρήσεις;

ΕΠΕΞΗΓΗΣΗ: Πολυεθνική θεωρείται οποιαδήποτε εταιρεία διεξάγει εμπόριο και/ή συντονίζει την παραγωγή της σε δύο ή περισσότερες χώρες. Το μέγεθος της εταιρείας δεν αποτελεί κριτήριο.

Παρακαλώ δηλώστε τον βαθμό ***συνεργασίας*** της επιχείρησης σας σε όλους τους παρακάτω τομείς:

Είδος Συνεργασίας	(βαθμολογείστε από το 1[=καθόλου συνεργασία] έως το 5[= πολύ έντονη συνεργασία])
Εμπορικός Συνέταιρος	O O O O O 1 2 3 4 5
Η εταιρεία σας είναι προμηθευτής πολυεθνικής.	O O O O O 1 2 3 4 5
Η εταιρεία σας προμηθεύεται **άμεσα** προϊόντα από πολυεθνική-ες.	O O O O O 1 2 3 4 5
Έρευνα και ανάπτυξη προϊόντων και επιχειρηματικών μοντέλων/μεθόδων	O O O O O 1 2 3 4 5
Συνεργασία στην εκπαίδευση προσωπικού	O O O O O 1 2 3 4 5
Άλλο είδος συνεργασίας (παρακαλώ αναφέρετε)	O O O O O 1 2 3 4 5
Ολικός βαθμός συνεργασίας (άθροισμα των παραπάνω)	O O O O O 1 2 3 4 5

Ερώτηση 15.
Πιστεύετε ότι το περιβάλλον και ο τομέας που δραστηριοποιείται η εταιρεία σας χαρακτηρίζονται από έντονο ανταγωνισμό; Παρακαλώ αναφέρετε το επίπεδο ***ανταγωνισμού*** που υπάρχει στην αγορά που απευθύνεστε.

(βαθμολογείστε από το 1[=καθόλου ανταγωνισμός] έως το 5[= πολύ έντονος ανταγωνισμός])

Μη ανταγωνιστικό ← → Έντονα ανταγωνιστικό

O O O O O
1 2 3 4 5

Πιστεύετε ότι αίτια για το επίπεδο ανταγωνισμού είναι:	(βαθμολογείστε από το 1[=καθόλου] έως το 5[=πάρα πολύ])				
Ο κορεσμός του συγκεκριμένου τομέα.	O 1	O 2	O 3	O 4	O 5
Ο υψηλός ρυθμός τεχνολογικής εξέλιξης.	O 1	O 2	O 3	O 4	O 5
Άλλοι παράγοντες (παρακαλώ αναφέρετε ποιοι) Παράγοντας 1	O 1	O 2	O 3	O 4	O 5
Παράγοντας 2	O 1	O 2	O 3	O 4	O 5

Ερώτηση 16.
Κατά ποιό βαθμό πιστεύετε ότι η ενσωμάτωση ηλεκτρονικών υπολογιστών (ή οποιασδήποτε άλλης νέας τεχνολογίας που τυχόν χρησιμοποιείτε) στην επιχείρηση σας ήταν μια ***πολύπλοκη*** και ***χρονοβόρα*** διαδικασία;

(βαθμολογείστε από το 1[=καθόλου] έως το 5[=πάρα πολύ])

Πολυπλοκότητα

O O O O O
1 2 3 4 5

Ερώτηση 17.

Πριν από την αγορά και ενσωμάτωση του συστήματος υπολογιστών (ή οποιασδήποτε άλλης νέας τεχνολογίας που τυχόν χρησιμοποιείτε) έτυχε κάποιο στέλεχος της επιχείρησης σας να ***δει*** την συγκεκριμένη τεχνολογία να λειτουργεί σε άλλη επιχείρηση;

(παρακαλώ σημειώστε **X**)

Ναι	
Όχι	

Ερώτηση 18.

Πριν από την αγορά και ενσωμάτωση του συστήματος υπολογιστών (ή οποιασδήποτε άλλης νέας τεχνολογίας που τυχόν χρησιμοποιείτε) είχε κάποιο στέλεχος της εταιρείας σας την ευκαιρία να ***δοκιμάσει*** την εφαρμογή;

Ναι	
Όχι	

Ερώτηση 19.

Κατά ποιό βαθμό ήταν η τεχνολογία που υιοθετήσατε (σε όλες τις μορφές τις) ***συμβατή*** με τις επιχειρησιακές σας δομές και τον τρόπο με τον οποίο δουλεύετε γενικότερα;

(βαθμολογείστε από το 1[=καθόλου] έως το 5[=πάρα πολύ])

Συμβατότητα

O	O	O	O	O
1	2	3	4	5

Ερώτηση 20.

Ανακαλύψατε ότι έπρεπε να γίνουν σημαντικές ***αλλαγές*** στις υπάρχουσες δομές, συνήθειες και στην υπάρχουσα τεχνολογική υποδομή της επιχείρησης σας έτσι ώστε να προσαρμοστούν στις εφαρμογές ηλεκτρονικών υπολογιστών; Παρακαλώ αναφέρετε το μέγεθος αυτών των αλλαγών.

(βαθμολογείστε από το 1[=καθόλου αλλαγές] έως το 5[=μεγάλες αλλαγές])

Αλλαγές στην επιχειρησιακή δομή, τεχνολογία

O	O	O	O	O
1	2	3	4	5

Ερώτηση 21.

Αν η επιχείρηση σας έχει πρόσβαση στο ***Διαδίκτυο*** (internet), τι είδος σύνδεσης χρησιμοποιείτε; (παρακαλώ σημειώστε **X**)

Αναλογική Τηλεφωνική Γραμμή (PSTN 56kbps)		Γραμμή xDSL	
Τηλεφωνική Γραμμή ISDN (64/128 Kbps)		Μισθωμένη Γραμμή	
Άλλη (παρακαλώ αναφέρετε)	....	Δεν γνωρίζω / Δεν απαντώ	

Ερώτηση 22.

Εάν η εταιρία σας έχει πρόσβαση στο Διαδίκτυο (internet) με οποιαδήποτε από τις παραπάνω γραμμές, παρακαλώ αναφέρετε το ***έτος*** κατά το οποίο εγκαταστάθηκε η κάθε γραμμή.

Είδος Σύνδεσης	**Έτος Εγκατάστασης**
Αναλογική Τηλεφωνική Γραμμή (PSTN 56kbps)	
Τηλεφωνική Γραμμή ISDN (64/128 Kbps)	
Γραμμή xDSL	
Μισθωμένη Γραμμή	
Άλλη (παρακαλώ αναφέρετε)	
Δεν γνωρίζω / Δεν απαντώ	

Παράδειγμα:

Είδος Σύνδεσης	**Έτος Εγκατάστασης**
Αναλογική Τηλεφωνική Γραμμή (PSTN 56kbps)	1995
Τηλεφωνική Γραμμή ISDN (64/128 Kbps)	1998
Γραμμή xDSL	-
Μισθωμένη Γραμμή	2001

Ερώτηση 23.

Σε ποιους τομείς πιστεύετε ότι η εταιρεία σας έχει βελτιώσει την **παραγωγικότητα** της μετά την ενσωμάτωση εφαρμογών ηλεκτρονικών υπολογιστών;

(βαθμολογείστε από το 1[=καθόλου βελτίωση] έως το 5[=μεγάλη βελτίωση])

Τομέας Επιχειρηματικής Δραστηριότητας	**Βαθμός Βελτίωσης Παραγωγικότητας**				
Αποθήκη και παραγγελίες	O 1	O 2	O 3	O 4	O 5
Λογιστήριο και Χρηματοοικονομικά	O 1	O 2	O 3	O 4	O 5
Βάσεις Πληροφοριών	O 1	O 2	O 3	O 4	O 5
Διαφήμιση/ Μάρκετινγκ	O 1	O 2	O 3	O 4	O 5
Υπηρεσίες και υποστήριξη πελατών	O 1	O 2	O 3	O 4	O 5
Παραγωγή	O 1	O 2	O 3	O 4	O 5
Λήψη Αποφάσεων	O 1	O 2	O 3	O 4	O 5
Επιχειρηματική Δικτύωση/Γνωριμίες	O 1	O 2	O 3	O 4	O 5
Ανθρώπινο Δυναμικό (διαχείριση προσωπικού)	O 1	O 2	O 3	O 4	O 5

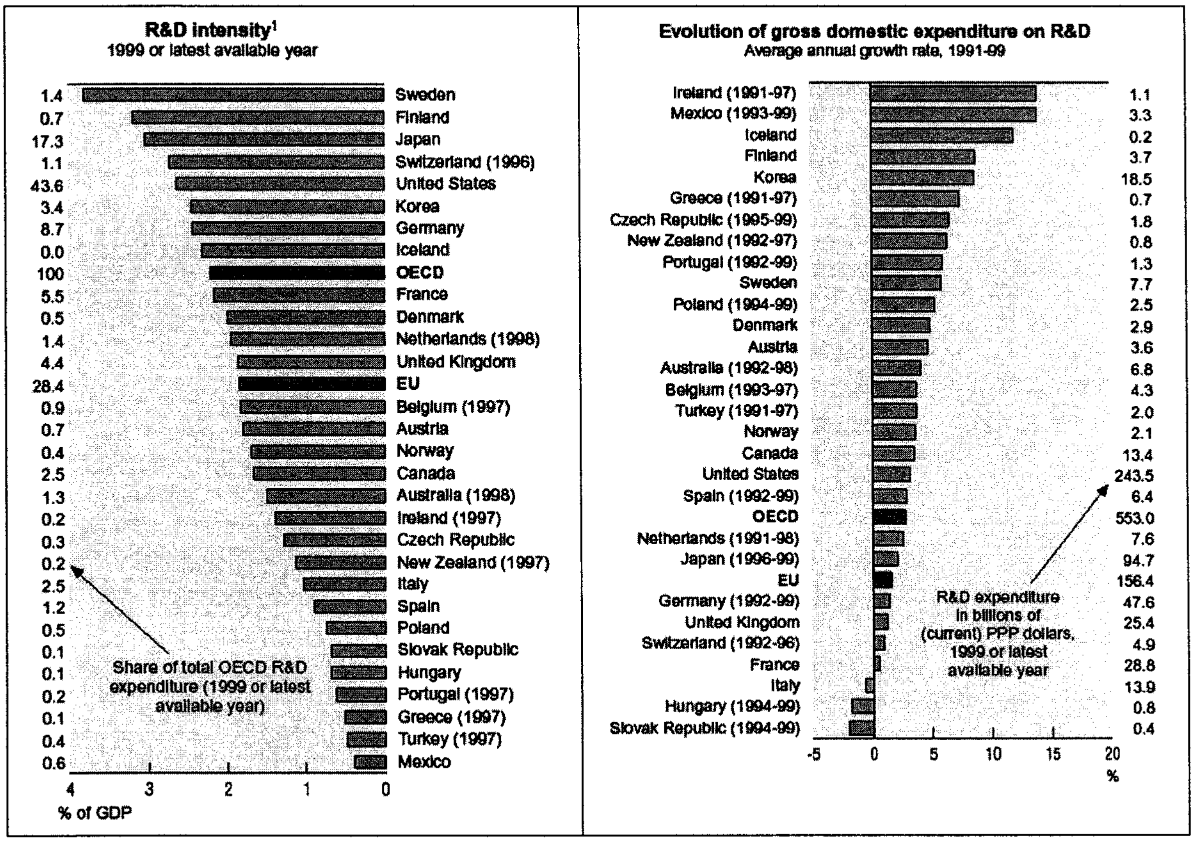
ΤΕΛΟΣ

Appendix 2 – Government Initiatives for the Promotion of Knowledge Flows

Government Initiatives Aimed at Promoting Firm Interaction and Knowledge flows.
Industrial clustering for knowledge flows is promoted in the context of the key action **"Technology Parks"**, which aims at enhancing interaction between firms and between firms and Research Institutes. In the same line, GSRT has launched a financial scheme to support the development of **Liaison Offices** in Universities, which promote the exploitation of scientific research.
The Technology Brokerage Programme (Technomesiteia): Conceived in 1995 to enhance technology flows from foreign to Greek actors, it supported activities like technology audits in the companies users of new technologies, market research about suitable available technologies, organization and carrying out negotiations between suppliers and users of technology etc.)
The **Performance Financing Programme** (XAT): The programme aims to distribute the risk of innovation financing amongst three parties i.e the technology supplier, the technology user and the financial institution.
The **Programme for Target Research Fellowships** (YPER) and the **Programme for Advancing Human Capital** (PENED): Both programmes aimed at creating a pool of highly educated persons who have actually dealt with production problems. At the same time it was expected that the programmes would highlight, especially for firms, the importance of applied research and innovation. Projects funded under these initiatives should focus in specific industrial needs exploiting in the same time human potential from the academic domain.
The **Programme "Human Networks of Knowledge Promotion"**: The focus of the programme is in creating closer interaction and networking between researchers and managers in companies in order to diminish intellectual isolation, improve technology transfer and offer scope for interdisciplinarity. Support is provided for travel expenses, organization of workshops, information material etc.
The **Programme for Best Practice Bench-marking** (PAFOS): This programme is for the determination and assimilation of standard practices of new technologies, focusing in topics of technological modernization. PAFOS encourages collaboration between at least one firm and one consultant in technology transfer, supporting the identification and absorption of new technologies.
Source: Kastelli and Tsakanikas (2000: 6-7)

Appendix 3 – International R&D Statistics and Policy Initiatives

(i) R&D Tables



Source: OECD (1997: 10, 13)

(ii) Policy Document Extracts

"**Technology diffusion**

So how, in the Panel's view, should the Commission develop a more innovative culture? Technology diffusion is a key element here. US markets are more efficient at transferring technology from universities and institutes to firms. The Davignon Panel recommends that the Commission's Programme directors and managers have clear responsibility for ensuring the diffusion of the technology developed within their Programmes into the marketplace for commercial exploitation. "Whilst the most successful outcome is one in which project participants commercialise their own findings, other avenues of exploitation need to be vigorously pursued with non-participants when this does not occur. In such circumstances, Programme directors and managers need to have contact with the venture capital community," the Panel maintains."

Source: EC (1997), "Promoting Innovation in Framework 5", Innovation and Technology Transfer, May, http://www.cordis.lu/itt/itt-en/97-3/policy.htm

Appendix 4 – Correspondence

"ADAPT – Technology Transfer Initiative, Greece"

From: Vasilis Papadopoulos [email address withheld], Head of IT EOMMEX, Adapt Supervisor, Tue 20/04/2004 19:34

[ENGLISH TRANSLATION]

Dear Mr Pontikakis,

[...] the programme in question named 'EINETE' took place as part of the overall EU-sponsored 'ADAPT' framework in which EOMMEX participated, the National Technical University of Athens and two private companies, namely EXPERTCAM LTD and OMEGA S.A. The programme in question was completed successfully two years ago [...]

During the course of the programme almost 50 companies participated. [...] the identity of which cannot be revealed due to data protection legislation.

Sincerely yours,

Vasilis Papadopoulos

[ORIGINAL IN GREEK]

Αγαπητέ κύριε Ποντικάκη,

Σας ευχαριστώ πολύ για τα καλά σας λόγια και σας εύχομαι καλή επιτυχία στους στόχους σας. Το συγκεκριμένο πρόγραμμα το οποίο ονομάζεται ΕΙΝΕΤΕ έγινε στα πλαίσια *της* κοινοτικής πρωτοβουλίας ADAPT και συμμετείχε ο ΕΟΜΜΕΧ, το Εθνικό Μετσόβιο Πολυτεχνείο και δύο ιδιωτικές εταιρίες η EXPERTCAM ΕΠΕ και η ΩΜΕΓΑ Α.Ε. Το συγκεκριμένο πρόγραμμα ολοκληρώθηκε επιτυχώς πριν δύο χρόνια και η παρουσίασή του στον κόμβο του ΕΟΜΜΕΧ ήταν συμβατική υποχρέωση του προγράμματος. Στο διάστημα της υλοποίησης του προγράμματος έγινε μια καταγραφή 50 περίπου επιχειρήσεων στον κλάδο των μηχανουργικών κατασκευών αλλά αυτό δεν μπορεί να δημοσιευθεί λόγω του νόμου περί προστασίας προσωπικών δεδομένων. Επιπροσθέτως σας ενημερώνω ότι η εφαρμογή που υλοποιήθηκε λειτούργησε με επιτυχία σε μία επιχείρηση κατά τη διάρκεια υλοποίησης του προγράμματος ενώ έκτοτε η επιχείρηση EXPERTCAM ΕΠΕ το έχει εγκαταστήσει και σε άλλες εταιρίες. Θεωρώ λοιπόν ότι το πρόγραμμα είχε επιτυχία.

Με εκτίμηση
Βασίλης Παπαδόπουλος
Προϊστάμενος Πληροφορικής ΕΟΜΜΕΧ

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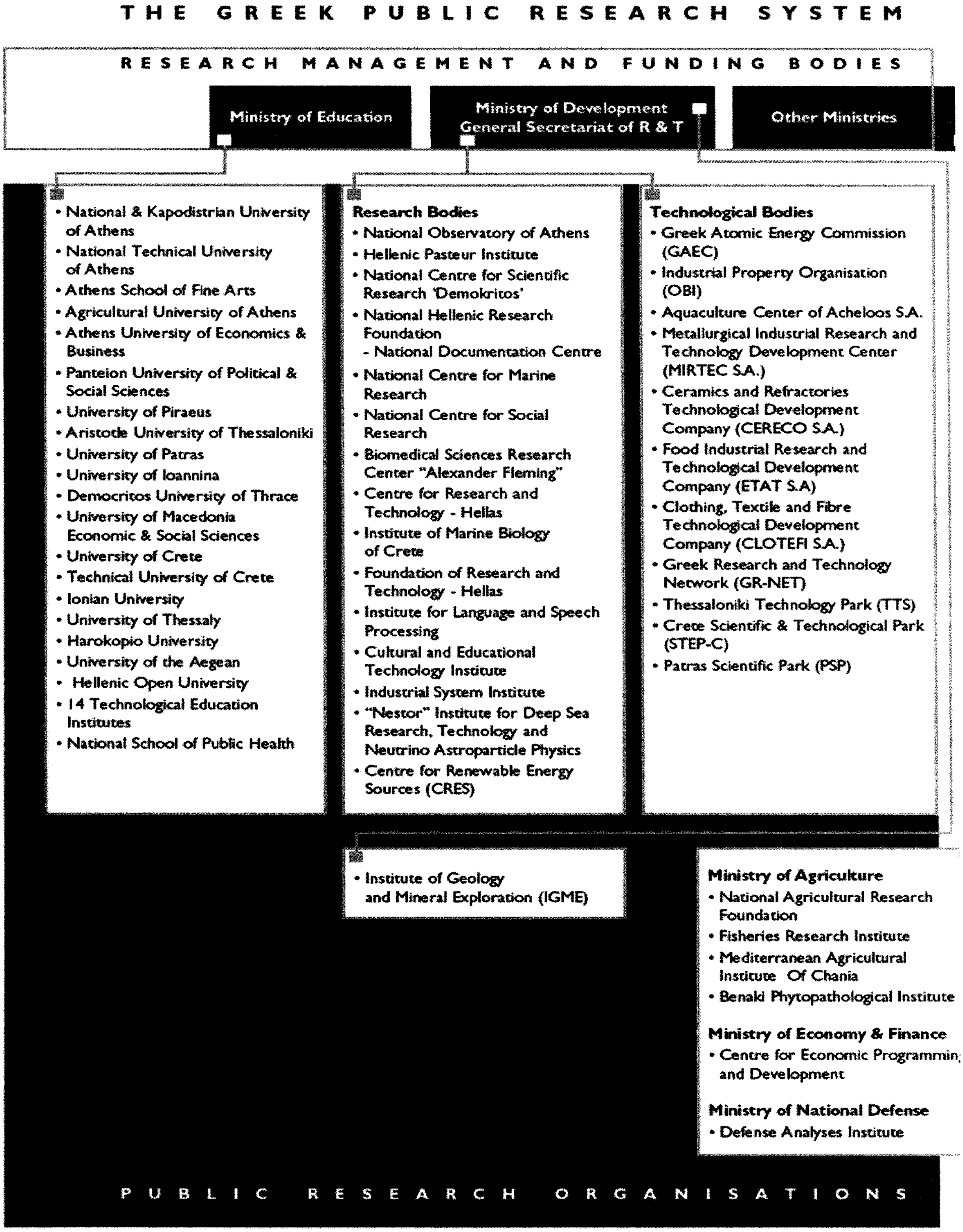
Appendix 5 – The Greek Public Research System



Appendix 6 - List of Acronyms

ADSL – Asymmetric Digital Subscriber Line
AGET – General Cement Corporation (Greece)
ASEAN –Association of Southeast Asian Nations
AT&T – American Telephone and Telegraph Company (US)

B2C – Business to Consumer
B2B – Business to Business
BERD – Business Expenditure on Research and Development

CPI – Consumer Price Index
CPI – Corruption Perceptions Index

DEH – Public Electricity Service (Greece)
DIVX – DIgital Video eXperts Encoding Format
DTP – Desktop Publishing

EBEA – Athens Chamber of Commerce (Greece)
EBPP – Electronic Bill Presentment and Payment
EDI – Electronic Data Interchange
EEC – European Economic Community
EFT – Electronic Funds Transfer
EMU – European Monetary Union
EOMMEX - Hellenic Organisation for Small and Medium Sized Enterprises and Handicraft (Greece)
EORG – European Opinion Research Group
EPAN – Executive Programme for Competitiveness
EPET – Research and Development Executive Programme
EPO – European Patents Office
EPOS – Electronic Point of Sale
ESIS - European Survey of Information Society
ETHEL – Athens Metropolitan Transport Corporation (Greece)
EU – European Union

FAT – File Allocation Table
FDI – Foreign Direct Investment
FORTH – Greek Company for Telecommunication and Telematic Applications (Greece)

GDP – Gross Domestic Product
GERD – Gross Expenditure on Research and Development
GPL – General Public License
GPS – Global Positioning System
GSM – Global System for Mobile communications
GSRT – General Secretariat for Research and Technology (Greece)

HBA – Hellenic Banks Association (Greece)
HL – Hosmer and Lemeshow

IBM – International Business Machines
ICANN - The Internet Corporation for Assigned Names and Numbers
ICQ – I Seek You
ICT – Information and Communication Technology
IEPC – Internet Enabled Personal Computer
IM – Instant Messaging
IOBE – Foundation for Economic and Industrial Research (Greece)
IRC – Innovation Relay Centre
IPRC – International Planning Research Corporation
IT – Information Technology

LPM – Linear Probability Model
LR – Likelihood Ration Statistic
LZW – Lempel-Ziv-Welch Computer Archive Compression

ML – Maximum Likelihood
MMC – MultiMedia Card (flash memory card format for storage)
MNE – Multinational Enterprise
MPEG4 – Moving Picture Experts Group, Standard 4 for Multimedia Applications

NAFTA – North American Free Trade Agreement
NGO – Non Governmental Organisation
NTFS – Network Technology File System

OBI – Industrial Property Organisation (Greece)
OECD – Organisation for Economic Cooperation and Development
OFSTED – Office for Standards in Education
OPEC – Organisation of Petroleum Exporting Countries
OS/2 – IBM Operating System 2

PC – Personal Computer
PPP – Purchasing Power Parity
PRI – Public Research Institute

R&D – Research and Development
RJV – Research Joint Venture

S&T – Science and Technology
SD – Secure Digital (flash memory card format for storage)
SME – Small and Medium Enterprise

TBP – Technological Balance of Payments

TCP/IP – Transmission Control Protocol/Internet Protocol
TFP – Total Factor Productivity
TPT – Technology Park of Thessaloniki

UN – United Nations
UNCTAD – United Nations Conference on Trade and Development
USPO – United States Patents Office

VoIP – Voice over Internet Protocol
VHS – Video Home System

WMV – Windows Media Video

XD – Extreme Digital Memory Card (flash memory card format for storage)

Appendix 7 – Pearson Bivariate Correlations

		Y	FSIZE	FGROWTH	CAPAVAIL	CONCTR	MNELNK	PREVXP	RELADV	COST	TRIAL	COMPLX	COMPBL	OBSRV	LIFEXP	DCT5	SECTOR	DM1
Y	Pearson Cc	1	0.150654	-0.017383	0.433208	0.158414	0.017107	0.36891	0.122312	-0.222966	0.101265	0.00989	0.183447	0.018712	-0.262575	0.28646	0.076118	-0.431238
	Sig. (2-taile	.	0.134613	0.863705	6.73E-06	0.115445	0.865852	0.000159	0.225396	0.025762	0.316102	0.922202	0.067708	0.853399	0.00831	0.00386	0.451628	7.49E-06
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
FSIZE	Pearson Cc	0.150654	1	0.290715	0.142905	0.022929	0.292394	0.077626	0.387842	-0.340946	0.302973	0.124701	0.119022	0.103221	-0.098014	0.158154	-0.014582	-0.204441
	Sig. (2-taile	0.134613	.	0.003343	0.156081	0.82086	0.003157	0.442692	6.69E-05	0.000518	0.002184	0.216397	0.238217	0.306799	0.331967	0.116051	0.885507	0.041319
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
FGROWTH	Pearson Cc	-0.017383	0.290715	1	0.206419	-0.047557	0.224525	-0.116185	0.181299	-0.117321	-0.088367	-0.174262	0.165677	-0.240848	-0.096199	-0.145538	-0.216959	0.07627
	Sig. (2-taile	0.863705	0.003343	.	0.039353	0.638459	0.024718	0.249673	0.071045	0.245042	0.38197	0.082917	0.099486	0.015785	0.341041	0.148518	0.030143	0.45072
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CAPAVAIL	Pearson Cc	0.433208	0.142905	0.206419	1	-0.079733	-0.057654	0.153491	0.00798	-0.078529	-0.065847	-0.100069	0.047961	-0.051276	-0.100987	0.045438	-0.045328	-0.324855
	Sig. (2-taile	6.73E-06	0.156081	0.039353	.	0.430368	0.568836	0.127344	0.937191	0.437386	0.515115	0.321883	0.635608	0.6124	0.31744	0.653503	0.654289	0.000975
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CONCTR	Pearson Cc	0.158414	0.022929	-0.047557	-0.079733	1	0.190891	-0.026326	0.336755	-0.137063	0.230923	0.022412	0.348283	-0.028796	-0.013672	0.209667	-0.040864	0.030972
	Sig. (2-taile	0.115445	0.82086	0.638459	0.430368	.	0.057113	0.794867	0.000613	0.173885	0.020803	0.824839	0.000384	0.776108	0.892609	0.036292	0.686456	0.759684
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
MNELNK	Pearson Cc	0.017107	0.292394	0.224525	-0.057654	0.190891	1	-0.054388	0.430582	-0.114446	0.368471	0.075194	0.529761	0.013511	0.023837	-0.032614	0.029824	-0.094967
	Sig. (2-taile	0.865852	0.003157	0.024718	0.568836	0.057113	.	0.590963	7.76E-06	0.256878	0.000162	0.457158	1.45E-08	0.893867	0.813895	0.747357	0.768331	0.347292
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PREVXP	Pearson Cc	0.36891	0.077626	-0.116185	0.153491	-0.026326	-0.054388	1	-0.048193	0.12136	0.046889	0.145485	-0.089735	0.054068	-0.232331	0.214927	0.103398	-0.510426
	Sig. (2-taile	0.000159	0.442692	0.249673	0.127344	0.794867	0.590963	.	0.633966	0.229056	0.643188	0.148668	0.374617	0.593153	0.020018	0.03176	0.305965	5.79E-08
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RELADV	Pearson Cc	0.122312	0.387842	0.181299	0.00798	0.336755	0.430582	-0.048193	1	-0.468667	0.508475	-0.157889	0.598448	-0.022233	-0.098522	-0.122966	0.08861	-0.079614
	Sig. (2-taile	0.225396	6.69E-05	0.071045	0.937191	0.000613	7.76E-06	0.633966	.	8.76E-07	6.63E-08	0.116672	4.85E-11	0.826211	0.329458	0.222907	0.38066	0.431059
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
COST	Pearson Cc	-0.222966	-0.340946	-0.117321	-0.078529	-0.137063	-0.114446	0.12136	-0.468667	1	-0.397441	-0.003761	-0.323928	-0.122732	0.247627	-0.096692	-0.044933	-0.117751
	Sig. (2-taile	0.025762	0.000518	0.245042	0.437386	0.173885	0.256878	0.229056	8.76E-07	.	4.23E-05	0.970379	0.00101	0.223798	0.012993	0.338565	0.657113	0.243302
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
TRIAL	Pearson Cc	0.101265	0.302973	-0.088367	-0.065847	0.230923	0.368471	0.046889	0.508475	-0.397441	1	0.172613	0.582851	0.541614	0.125809	0.179379	0.045549	-0.097854
	Sig. (2-taile	0.316102	0.002184	0.38197	0.515115	0.020803	0.000162	0.643188	6.63E-08	4.23E-05	.	0.085916	1.99E-10	5.93E-09	0.212311	0.074139	0.652716	0.33276
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
COMPLX	Pearson Cc	0.00989	0.124701	-0.174262	-0.100069	0.022412	0.075194	0.145485	-0.157889	-0.003761	0.172613	1	0.024413	0.402702	0.104381	0.237112	-0.063179	-0.019198
	Sig. (2-taile	0.922202	0.216397	0.082917	0.321883	0.824839	0.457158	0.148668	0.116672	0.970379	0.085916	.	0.809479	3.27E-05	0.301363	0.017535	0.532316	0.849632
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
COMPBL	Pearson Cc	0.183447	0.119022	0.165677	0.047961	0.348283	0.529761	-0.089735	0.598448	-0.323928	0.582851	0.024413	1	0.235896	-0.008528	0.098444	0.065547	-0.144344
	Sig. (2-taile	0.067708	0.238217	0.099486	0.635608	0.000384	1.45E-08	0.374617	4.85E-11	0.00101	1.99E-10	0.809479	.	0.01814	0.932888	0.32984	0.517031	0.151912
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
OBSRV	Pearson Cc	0.018712	0.103221	-0.240848	-0.051276	-0.028796	0.013511	0.054068	-0.022233	-0.122732	0.541614	0.402702	0.235896	1	0.167053	0.205166	-0.025685	-0.091817
	Sig. (2-taile	0.853399	0.306799	0.015785	0.6124	0.776108	0.893867	0.593153	0.826211	0.223798	5.93E-09	3.27E-05	0.01814	.	0.096669	0.040589	0.799756	0.363589
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
LIFEXP	Pearson Cc	-0.262575	-0.098014	-0.096199	-0.100987	-0.013672	0.023837	-0.232331	-0.098522	0.247627	0.125809	0.104381	-0.008528	0.167053	1	0.183764	-0.05849	0.093644
	Sig. (2-taile	0.00831	0.331967	0.341041	0.31744	0.892609	0.813895	0.020018	0.329458	0.012993	0.212311	0.301363	0.932888	0.096669	.	0.067226	0.563238	0.354079
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
DCT5	Pearson Cc	0.28646	0.158154	-0.145538	0.045438	0.209667	-0.032614	0.214927	-0.122966	-0.096692	0.179379	0.237112	0.098444	0.205166	0.183764	1	0.003139	-0.159118
	Sig. (2-taile	0.00386	0.116051	0.148518	0.653503	0.036292	0.747357	0.03176	0.222907	0.338565	0.074139	0.017535	0.32984	0.040589	0.067226	.	0.97527	0.113816
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
SECTOR	Pearson Cc	0.076118	-0.014582	-0.216959	-0.045328	-0.040864	0.029824	0.103398	0.08861	-0.044933	0.045549	-0.063179	0.065547	-0.025685	-0.05849	0.003139	1	0.029872
	Sig. (2-taile	0.451628	0.885507	0.030143	0.654289	0.686456	0.768331	0.305965	0.38066	0.657113	0.652716	0.532316	0.517031	0.799756	0.563238	0.97527	.	0.76797
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
DM1	Pearson Cc	-0.431238	-0.204441	0.07627	-0.324855	0.030972	-0.094967	-0.510426	-0.079614	-0.117751	-0.097854	-0.019198	-0.144344	-0.091817	0.093644	-0.159118	0.029872	1
	Sig. (2-taile	7.49E-06	0.041319	0.45072	0.000975	0.759684	0.347292	5.79E-08	0.431059	0.243302	0.33276	0.849632	0.151912	0.363589	0.354079	0.113816	0.76797	.
	N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).